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UNIVERSITY OF ALBERTA

A NONPARAMETRIC ANALYSIS OF THE TRAVEL COST MODEL OF RECREATION DEMAND

by

PETER CHARLES BOXALL

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE
IN
AGRICULTURAL ECONOMICS

DEPARTMENT OF RURAL ECONOMY
EDMONTON, ALBERTA
FALL 1991

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ISBN 0-315-69944-2

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The undersigned certify that they have read and recommended to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled A NONPARAMETRIC ANALYSIS OF THE TRAVEL COST MODEL OF RECREATION DEMAND submitted by PETER CHARLES BOXALL in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL ECONOMICS.

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ABSTRACT

The Hotelling-Clawson-Knetsch (HCK) travel cost model has been a standard in non-market benefit valuation for recreation activities for over 30 years. Despite its widespread use, however, the consistency of the derived models describing recreation behaviour with the economic theory of choice have not been investigated.

In this thesis an HCK travel cost model using data gathered from 423 trips made by 226 Alberta sheep hunters to ten sites is examined in terms of its consistency with an implied hypothesis of utility maximization. The examination utilizes nonparametric demand theory, which tests choice data with agreement with the axioms of revealed preference, and includes analysis of the statistical significance of deviations from consistency. This study includes an attempt to derive the values of time to be used in the model using consistency with utility maximization as the selection criteria; an analysis of demand heterogeneity; and an investigation of potential separability of recreation sites within the model.

The findings of this study suggest that the HCK travel cost model incorporating no values of time is not consistent with a maintained hypothesis of utility maximization. In other words, the model is an invalid representation of the economic behaviour of recreationists. Using the degree and statistical significance of violations of the axioms of revealed preference as a guide, the following results were obtained: 1) When values of time are incorporated the model provided a "better" representation of economic behaviour; 2) Values of time based on wage rates calculated using income worked better than occupation based wage rates; 3) Stratifying the recreation choice set by various socioeconomic characteristics revealed a significant degree of demand

heterogeneity. Relatively homogeneous preferences were found in strata based on income, while some strata based on occupation and years of experience still exhibited a high degree and number of violations of the axioms; and 4) Choice behaviour in the sample of hunter data used in this study could be adequately represented by a utility function operating over ten sites rather than two sub-utility functions operating over an obvious grouping of the sites.

These results suggest that researchers should use caution in applying travel cost methodology to measure non-market recreation benefits. Values of time should be incorporated in travel cost models, and demand heterogeneity may be present in recreation data to an extent that stratification by socioeconomic variables and separate demand estimation on each strata may be required. This study suggests a promising approach in the search for accurate models to estimate non-market benefits. Use of nonparametric demand methodology may be useful in the pre-testing of recreation data for non-market valuation models; especially in the investigation of assumptions regarding values of time, demand heterogeneity, and the choice set of recreation sites.

ACKNOWLEDGEMENTS

When a government employee has been allowed the benefit of returning to university and obtaining a degree in a discipline so different from the traditional areas supported by the department in which he works, a number of special individuals merit recognition.

First, at the University of Alberta, I acknowledge with pleasure the support and guidance of Vic Adamowicz during my studies at the University of Alberta. His friendship, insights into the many nuances of economic theory, and his ability to apply the theory to the many practical problems faced by resource management professionals, has allowed me to broaden my perspective on many natural resource issues. In addition, Bill Phillips initially inspired my interests in resource economics and provided the impetus for me to undertake studies at the university.

Second, at Forestry Lands, and Wildlife, Mike Melnyk, who has been a special friend and colleague as well as my boss, provided significant assistance in gaining approval from our superiors for my educational leave. I also thank Tom Smith, Les Cooke, and Tom Mill for supporting and encouraging my st[illegible]s at various stages of completion.

I also thank Mark Anielski, Glen Armstrong, Dave Borutski, Alison Coyne, Mark Messmer, Blaine Staples, and Harry Stelfox for providing moral support, understanding, and assistance in many ways they probably did not realize.

Finally, I sincerely thank Lois, my wife and partner, for supporting my studies and many absences from home. She has always encouraged me and allowed me to do the best that I can in any endeavour I have undertaken. I also appreciate her artistic talent which she used in preparing the figures

in this thesis.

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1.0 INTRODUCTION

The Hotelling-Clawson-Knetsch (HCK) travel cost model has been used to estimate recreation benefits for over 30 years and has become a standard in non-market valuation procedures. This thesis is concerned with testing the travel cost model for consistency with the economic theory of choice. Consistency with this choice theory is critical if the travel cost model is to be used in the economic analysis of resource allocation. The investigation of the model's consistency with choice theory will involve the testing of choices of hunting sites made by a sample of big game hunters with the axioms of revealed preference. This approach, called nonparametric demand analysis by Varian (1982), has not been applied to the HCK travel cost model before.

In the remainder of this chapter, economic analysis of resource allocation is described, and the economic paradigm, in which the theory of choice plays a fundamental role, is briefly described. The problem of non-priced or non-market goods is raised in the context of economic analysis, and the current methods used to estimate their values are outlined. Finally, the objectives of the research reported here is outlined.

1.1 Background

Most economists believe that the policies and decisions made by public agencies would improve if the agencies considered a comparison of the costs and benefits of instituting a particular decision or policy. If costs outweighed benefits then perhaps the policy or decision should not be established. Economists, however, do not suggest that this principle is adequate to set policy; only that it be considered in decision making. The rigour applied to ascertaining and measuring potential costs and benefits would at least provide some suggestions as to potential outcomes, and these would force decision makers to clearly and objectively outline reasons for establishing a position.

The theory of welfare economics suggests that it is possible to value goods and services from the point of view of society as a summation of individual values, and that these values can be used to seek judgements about resource allocation. Welfare economics proposes that one could compare two or more states or situations in the world. One of these states, for example, could be the present, while the other might involve the advent of a particular allocation of resources occurring through some policy change. Comparison of these states through various criteria suggests what "should be" in the best interest of society as a whole. The question that remains, however, is what are these criteria?

A weak criterion which can be used to rank policies is the Pareto condition. This criterion states that a policy, A, is to be preferred to B if there is at least one person better off in A than in B, and that no one is worse off in A than in B. If these conditions hold, then A is a Pareto improvement. In practice, the Pareto criterion is rarely met because despite many Pareto allocations, there are very few Pareto improvements.

A criterion related to the Pareto criterion is the compensation principle proposed by Kaldor (1939) and Hicks (1939). This principle refers to a change from state A to B which is an improvement if it is hypothetically possible to undertake a costless redistribution through compensation paid by gainers to losers. The compensation principle refers to hypothetical redistribution because the decision to actually pay compensation is a separate decision (Boadway and Bruce 1984). This criterion is useful in that it allows a ranking of policy changes by considering if gainers after a change can potentially compensate losers.

The compensation principle is used by applied economists in benefit-cost analysis. In benefit-cost analysis policies are judged upon economic efficiency rather than distributional concerns. Efficiency in this context refers to resources being put to their most productive or highest valued use. Distributional inequities that may result from using economic efficiency as a means of decision-making could be addressed through potential lump-sum payments by decision makers - in essence a compensation payment. Thus, benefit-cost analysis tries to measure in monetary terms the gains and losses to those affected by a policy change.

In accepting the tenets of welfare economic theory and particularly benefit-cost analysis, one must follow the underlying fundamentals of economic theory. Silberberg (1990) states the economic paradigm as: "economics .... seeks refutable explanations of changes in human events on the basis of changes in observable constraints, utilizing universal postulates of behaviour and technology, and the simplifying assumption that the unmeasured variables ("tastes") remain constant." The things in this paradigm that set economic theory apart from other social science theories are its postulates of human behaviour, particularly behaviour relating to choice, and its focus on constraints or opportunities. Given these postulates and various constraints, economic theory provides predictions about the behaviour of economic agents such as individuals and firms.

One foundation of the economic paradigm involves a theory of choice[1]. This theory involves two major assumptions. The first is that when individuals face a choice between two bundles of goods they have preferences for one over the other; in other words, they can rank them. The second is that individuals are acting through their behaviour to maximize an overall level of satisfaction or utility. Economic theory couples these major assumptions with others involving the structure of preferences (i.e. transitivity, nonsatiation etc.), to arrive at some predictions about how individuals will behave given changes in opportunities or constraints.

These assumptions, when applied in the context of trade between individuals and firms, result in a concept of value for goods and services. The value of something is the most an individual is willing to give up to obtain it. In an economic setting the marginal value is called a price, which reflects the application of a money metric applied to the terms of trade.

1.2 The Problem: Non-Priced Goods and Services

In many cases prices are determined in markets which represent established formal processes for buying and selling goods and services. Goods for which these prices can be established are called pure private goods (Mitchell and Carson 1989). However, for a class of goods called public goods, prices cannot be determined because the goods are not traded in markets. Public goods can be broadly defined as goods that are jointly consumed by more than one individual. Mitchell and Carson (1989) classify public goods as one of two types: pure public goods which are characterized by non-rivalry/congestion and non-excludability; and quasi-private goods which have some price attached to them, but that price is not established in the marketplace. An example of a pure public good is air. Examples of quasi-private goods include recreational hunting, in which permits must be purchased at a price that is established by the government and not solely by trading them in markets.

---

[1] Deaton and Muellbauer (1980) provide a comprehensive overview of this theory.

The existence of public goods creates problems for benefit-cost analysis. How does one compare the market derived prices of private goods with the preferences individuals may have for public goods? How are preferences for public goods revealed?

In most benefit-cost analyses many public goods values are at or close to zero due to an absence of market prices. This assumes that individuals gain no marginal economic benefit from using public goods. However, the concept of consumer surplus can be used to value public goods. This concept was first introduced by Dupuit (1844) who was interested in analyzing the benefits and costs of a publicly funded bridge, a classic example of a public good. Later, Marshall (1920:124) formally defined consumer surplus as: "the excess of price which he would be willing to pay rather than go without the thing, over that which he actually does pay is the economic measure of this surplus of satisfaction". Thus, consumer surplus holds promise for decision makers wishing to measure the benefits of public goods.

The estimation of consumer surplus is dependent on deriving demand schedules. For nonmarket goods like public goods, this results in considerable difficulty since demand functions for these goods and services are unobservable. This problem has been called the "problem of preference revelation" by Johansson (1987). To answer this concern economists have developed a set of methods to estimate the values or benefits of public goods. These methods, called nonmarket valuation methods, fall into one of two categories: direct or indirect methods.

The direct method has its roots in Davis's (1963) attempt to estimate the benefits provided by outdoor recreation. The method, called contingent valuation, involves the administration of questionnaires to individuals in which a market for the public good is simulated. Individuals are essentially prompted to reveal what they would be willing to pay for various provisions of the public good. This method has received a great deal of attention by economists (and many others) and has become one of the standard methods used in considering public goods valuation issues in benefit-cost analysis (see Mitchell and Carson (1989) for an overview of this method).

Alternatives to the contingent valuation method (CVM) include a class of indirect methods. These methods rely on observing actual market choices made by individuals associated with the consumption of a public good, and indirectly inferring values from these observations. One of the most popular of these methods is the travel cost method. This method uses the market prices of travelling to a specific site (which is usually a public good) to establish a demand function for the site. From this demand relationship, consumer surplus can be estimated.

There is considerable debate on whether the CVM or the travel cost model provides the most accurate estimate of economic values. A number of studies (e.g. Knetsch and Davis 1966; Bishop and Heberlein 1979) have found relatively close agreement between values derived from these methods.

However, the question remains whether these methods can accurately reflect the underlying preference structure of consumers. This question is critical in that these values are compared to market values in benefit-cost analysis.

Each of these standard methods operates within the economic paradigm in a different way. The CVM makes no assumptions about the structure of preferences. For example, consumers could be questioned directly about their willingness to pay for certain levels of provision of a public good. Their answers are related to their individual preference structure, and when combined with the answers of other individuals are assumed to represent demands and/or welfare measures. The travel cost model, however, assumes a particular preference structure in interpreting actual travelling behaviour, and uses this preference structure to estimate demands and/or welfare measures.

A key element in the use of these methods to measure consumer surplus accurately is the validity of their underlying assumptions in the overall economic model. The question of the validity of these methodologies is critical if the values derived by CVM or TCM are to be compared to market prices of goods and services. This thesis will investigate the assumptions inherent in the most popular form of the travel cost model.

The travel cost model has become one of the standard methods used to value the recreational services provided by public goods. The question of this model being consistent with the economic theory of choice has not been formally raised. Yet this question is of some significance, for if the travel cost model is not consistent with economic theory, then use of this method to derive economic values is seriously undermined. In the economic literature, however, this question is frequently investigated in demand systems for market goods. Generally, nonparametric demand analysis (Varian 1982) is used to examine the preference structures underlying the choices observed for market goods (e.g. Chalfant and Alston 1987). Because weak complementarity[2] between public goods (say a park) and private goods (e.g. gasoline) is assumed in travel cost methodologies, one should be able to apply nonparametric demand analysis in investigating choice behaviour assumed in travel cost models.

1.3 Study Objectives

This study utilizes nonparametric demand analysis in an examination of the travel cost method. The primary objective of the study is to determine if the underlying recreation behaviour assumed in the development of a traditional travel cost model is consistent with the implied economic theory of choice. The study proceeds by testing a simple form of the travel cost model using hunting site choice data gathered from big game hunters in Alberta. The second objective is to examine some conditions under which the traditional travel cost model could be consistent with choice theory. Using consistency as a selection or an analytical criterion, specific objectives are to reveal an implicit value of time in travel cost studies, identify the existence and significance of demand heterogeneity, and examine potential separability of recreation sites or site choice sets within a travel cost model.

---

[2] A public and private good are weakly complementary if when the consumption of the private good is zero, the marginal value or willingness to pay for the public good is zero (Freeman 1979:74, 197). Weak complementarity is assumed to hold for use of a recreation site in that recreation benefits are zero if one does not travel to the site. This assumption can understate total benefits if nonuse benefits, such as option or preservation demands, are associated with a site.

The remainder of this thesis is organized as follows: Chapter 2 discusses the travel cost model in detail, and provides a context in which the model can be analyzed in terms of the economic theory. Chapter 3 describes nonparametric demand analysis, including the axioms of revealed preference and some current procedures used to estimate the statistical significance of consistency of choice data with these axioms. Chapter 4 outlines the data and specific methodologies used in the examination of the travel cost model. Chapters 5 and 6 outline the results and conclusions of the investigation.

2.0 THE TRAVEL COST MODEL

2.1 The Traditional Travel Cost Model

In 1947 the United States National Park Service requested from several economists methods with which to value the services parks provided. At the time the Parks Service wanted to measure "economic benefits derived from these areas in excess of economic returns and benefits that would accrue if the areas were used for other purposes" (McConnell 1985). One of the economists who responded to the Parks Service was Harold Hotelling who provided a proposal now called the travel cost method. His proposal, although apparently ignored by the Parks Service, was eventually applied by Trice and Wood (1958), Clawson (1959), and others and is now called the travel cost model (TCM). The TCM has since become one of the standard methods used to measure recreation benefits.

Hotelling's idea was that recreationists incur costs to visit recreation sites that vary in proportion to the distance they must travel between their homes and that site. Under an assumption of weak complementarity between the costs of a private good (travel) and the availability of the recreation site (normally publicly provided), these costs can be considered a proxy for the price of a trip to the site. At different prices (i.e. distances), different quantities (numbers of trips) will be consumed (taken), and these price quantity variations identify a demand curve for the site. Burt and Brewer (1971) and Rosenthal et al. (1984) provide a good elaboration of this concept. Consumers are homogeneous in all respects except location, are widely dispersed geographically, and are transported to the commodity for consumption rather than the reverse. Thus, for a recreation site j they face a price, p_j with two additive components: a user fee or entrance price, p_0 which is common to all consumers; and a "shipping cost", t_j. This latter component is related to transportation and is a production input factor that varies by consumer location (Rosenthal et al. 1984). Consumers who live at different geographical locations will face different prices for the site because of the variability of this component. Summing the quantities of trips demanded for the site at the prices described above yields an aggregate demand curve from which benefits can be derived.

The model as originally conceived by Hotelling became what is now called the zonal travel cost model. This particular form of the model involves the aggregation of consumers into origin or distance zones (i), and regresses the visits per capita from each of these zones to the recreation site in question against travel costs and other variables. This can be represented by:

$$v_i = V(TC_i, S_i),$$

where v_i is visits per capita from origin i to the site, TC_i is the full cost of trips to the site from each of the i zones, and S_i is a vector of socioeconomic characteristics of individuals from the i zones recreating in site j. The total number of visits to site j is $\Sigma_i(POP_i v_i)$, where POP_i is the population of zone i. In order to identify the demand curve, entrance fees, P, are added incrementally to the travel costs such that $V(P) = \Sigma_i V([TC_i+P], S_i)$. P is increased until $V(P) = 0$. Once the demand curve is identified, the benefit measure, B, of site j is estimated by calculating the area under the demand curve or:

$$B=\int_{0}^{P^{*}} V(TC_{ij}+P,S_{ij})\,dP$$

where P^* is the choke price.

There are a number of examples where the travel cost model has been applied to estimate the recreational benefits associated with particular sites, and in some cases the collective benefits associated with certain recreational activities over a number of sites. Examples of the former include Knetsch (1964) who measured recreational benefits associated with a reservoir in the U.S. Examples of the latter are common. One of the first was attempted by Brown, Singh and Castle (1964). Their particular version involved estimating the benefits of recreational salmon fishing in the entire state of Oregon. This activity took place at a number of sites (n=35), and thus an aggregate travel cost model was developed. This particular version takes the form:

$$V_{ij}=(TC_{ij},S_{i})$$

where the same variables described above reflect the visits or costs of travelling from origin i to site j = 1,....,35. Using this model an aggregate benefit measure was calculated over all 35 sites for salmon fishing in the state. This form of model has been used extensively by economists with the U.S. Forest Service to value some outdoor recreational services provided by forests (see Sorg and Loomis 1984), and by fish and wildlife resources in various states (e.g. elk hunting in Idaho; Sorg and Nelson 1986).

The traditional travel cost models proposed above have important associated assumptions. These are: 1) the model assumes that all trips made to each of the sites are determined at one time (e.g. at the beginning of the season); 2) all individuals spend an equal and fixed amount of time at the site; 3) the main purpose of the trip is recreation; 4) individuals treat the entrance fee and travel costs as identical; 5) there is no utility in travelling to the site; 6) there are no substitute sites available. McConnell (1985), Smith (1989), and Fletcher et al. (1990) provide excellent overviews of these assumptions, and discuss other theoretical problems with the travel cost model. Generally, much of the empirical research with the TCM has involved issues in estimating the travel cost demand function, the calculation of net benefits, and the need to complete the analysis with imperfect data.

The issue of imperfect data provides additional interesting insights into the development of the TCM. Smith (1989) recognized that the early uses of TCMs involved the zonal form of TCM, and that they involved data consisting of visitation rates from individuals' counties of origin. Distances were measured from the recreation site to the centroid of each county of origin, and the socioeconomic characteristics of the recreationists were assumed to be representative of the average values of various socioeconomic variables derived from the counties. McConnell (1985), however, notes that the zonal model is theoretically inconsistent with economic theory (not based on a model of utility maximization). This is described in detail below.

The approach used to estimate the dependent variable in the zonal model involves visits per capita based on origin zones. This method involves the strong assumption that every recreationist residing in a zone has the same demand parameters. Fletcher et al. (1990) describe this assumption as the estimated demand being generated by a representative consumer whose behaviour reflects average behaviour in the zonal population. This assumption may not be consistent with economic theory which indicates that individual level data is preferred if the demand function is assumed to be generated via constrained utility maximization. This assumption is also necessary if the estimated demand function is to be used to compute welfare measures rather than predicting visitation rates. These concerns with the zonal method led researchers to utilize individual level data as the dependent variable in TCM.

The first investigation using individual level data as the dependent variable in a TCM was Brown and Nawas (1973). Their rationale was to compare the statistical efficiency of the parameters of the demand functions estimated both with individual level data and aggregate or zonal data. Since the publication of their paper a number of workers have utilized individual observations in travel cost models (e.g. McConnell and Strand 1981; Smith et al. 1983) and McConnell (1985) mentions that it has become common practice.

The application of utility maximization to travel cost models is explored in the remainder of this chapter, and issues resulting from this application are discussed.

2.2 The Utility Maximization Approach to Travel Cost Models

The economic foundation of the travel cost model essentially involves a model of utility maximization. Suppose a representative recreationist has preferences represented by a utility function, U, over the number of trips to a set of recreation sites and the consumption of all other market goods. This utility maximization problem can be represented by the following sets of equations:

$$\max U(v_1, \ldots, v_J, z)$$

$$S.T. \quad 1) \quad hw+M=Y=c(v_1, \ldots, v_J)+pz$$

$$2) \quad T=h+\sum_{j=1}^{J} v_j(t_1{}^j+t_2{}^j)+t_z,$$

where v_1 to v_J = are the number of trips to each of j recreation sites, z = a commodity bundle of all other goods, Y = income, w = the individual's wage rate, h = time spent working, M = non-wage income, c = out-of-pocket costs per trip, p = prices of all other goods, T represents the total time available, $t_1{}^j$ = travel time per recreation trip, $t_2{}^j$ = time spent on the recreation site per trip, and t_z = time spent consuming all other goods. The constraint used here represents what is called the full income constraint as it attempts to incorporate time explicitly in the budget. This method, first proposed by Becker (1965), is commonly applied in theoretical investigations of recreation demand (e.g. Smith et al. 1983). Assuming that non-wage income (M) = 0, the constraint can be rearranged as follows:

$$h=T-\sum_{j=1}^{J} v_j(t_1{}^j+t_2{}^j)-t_z$$

$$\therefore \quad w(T-\sum_{j=1}^{J} v_j(t_1{}^j+t_2{}^j)-t_z)=c(v_1, .. v_J)+pz$$

The constraint now identifies that full income is equal to expenses. This can be used to identify the full cost (c_j^*) of visiting a recreation site (j) as $c_j^*=w(t_1{}^j+t_2{}^j)+c_j$ with time variables valued at the wage rate, w, and c_j representing actual out-of-pocket expenditures involved in visiting the site.

The utility maximization approach to travel cost demand studies is useful in that it identifies a number of other critical issues in the travel cost literature and suggests ways of investigating them. In this study the following issues will be investigated: goods separability, the value of time in the recreation demand model, and demand heterogeneity.

2.3 The Issue of Goods Separability

The utility maximization problem identified in the previous section essentially involved two groups of goods: visits to a set of recreation sites with each site treated as a different good (v), and a group including all other goods (z) that could be consumed by an individual. Consider the following restructuring of the utility function, U:

$$U(H(v),G(z)),$$

which contains two "sub-utility" functions, one for visits to recreations sites (H(v)), and the other for all other goods (G(z)). If these groups of goods are separable, then the demand function for any of the goods in one group does not depend on the price of any good in the other group. Deaton and Muellbauer (1980) discuss other properties of separable utility functions. The concept of separability is related to the assumption that preferences within one group can be described independently of those for goods in other groups, and is related to the idea of branch budgeting (Fletcher et al. 1990). This has intuitive appeal in the study of recreation demand because the consumption of many non-recreation goods (e.g. toothpaste) probably has little if any influence on the demand for recreation.

Having assumed that the visits to recreation sites can be represented by a sub-utility function, the question remains about whether this function represents trips for **all** recreational activities. For example, can recreational hunting be considered separable from camping? The further separation of the recreation utility function into functions representing various recreational activities is implicitly assumed in recreation demand models, and is assumed in this study as well. This may not be an accurate representation of recreation demand behaviour, but is common due to the lack of data on alternative recreation activities (Fletcher et al. 1990).

An important extension of the travel cost demand model relating to concepts of separability arose due to concerns about site definition. Essentially the issue involved the need to understand alternative choices of sites available to the consumer for the same recreational activity, and whether trips to these alternate or substitute sites are separable from those site(s) under investigation (Fletcher et al. 1990). At the limit, one could assume a separate utility function for each site. However, it seems likely that the demands for recreation at a site would be affected by demands at other sites. Thus, this tactic may not represent reality. The most complex approach would be to group all sites together in the utility maximization model. The problem can perhaps be best addressed by assuming several sub-utility functions, each of which contain different subgroups of the set of sites available. For example consider the following utility functions:

$$\max\{U(v_1, v_2) \mid y = c_1 v_1 + c_2 v_2\};$$

$$\max\{U(v_3, \ldots v_{10}) \mid y = \sum_{i=3}^{10} c_i v_i\}$$

These represent a maximization problem involving two separable functions with associated budget constraints (excluding time for simplicity): one for two sites, and the other for an additional eight sites available to the recreationist for the same activity. The problem as outlined above now involves two demand systems, one for the two sites and the other for the remaining eight sites. Each of these will include the prices (or costs) of travelling to the alternate site(s) within each group.

The first applied work on the problem of multiple sites was done by Burt and Brewer (1971) who used a system of demands for interrelated recreation sites in determining the benefits of introducing a new site. Hof and King (1982) later showed that this method might be unnecessary if the prices of all sites were used as independent variables in the demand equation for one of the sites. They suggested that demand functions for each site could be estimated separately if the same independent variables (including cross price terms) were used in each equation. Subsequent research by Rosenthal (1987) and others has led to the understanding that including prices of substitute sites in the travel cost demand equation is a necessary practice.

In an ideal world the most accurate representation of behaviour associated with a specific recreational activity would involve knowledge of each individual's choice set of sites. However, a more realistic approach would be to test the assumption of separability utilized in a demand model by comparing various groupings of sites in applied work.

2.4 Investigations of the Budget Constraint: The Issue of the Costs of Time.

Perhaps the most perplexing issue in the travel cost literature is how to accurately calculate the total variable cost of travelling to the recreation site. Recall that the model of utility maximization (equation 1) identified that the full cost (c_j^*) of visiting site j (represented by $c_j^* = w(t_1^j+t_2^j)+c_j$), includes travel time (t_1^j) and on-site recreation time (t_2^j) priced at the wage rate w, and out-of-pocket travelling expenses, c_j. Incorporation of these costs in the demand model are critical if theoretically consistent estimates of recreation benefits are to be made.

The most obvious components of the cost are the out-of-pocket expenses for fuel, accommodation and other components that are related to the distance between an origin and site. However, early researchers (e.g. Clawson 1959; Knetsch 1963) recognized that the time required to visit a site may be a major component of the total cost. Knetsch (1963) in fact noted that omission of time costs would result in undervaluation of the site. These observations led to major efforts by a number of researchers to attempt to incorporate time in travel cost models. In general, three questions about time values have been addressed by this line of inquiry: 1) do we need to worry about time; 2) how do we measure it; and 3) what should we be measuring?

The answer to the first question seemed obvious. Knetsch's (1963) comment on values was addressed by Bishop and Heberlein (1979), McConnell and Strand (1981), and Wilman and Pauls (1987). They found that the value of time was a primary determinant of the estimated benefits of recreation sites, causing site values to vary up to four times. Fletcher et al. (1990) note that the transportation literature has addressed this question and that most studies have determined that it is an important consideration (see Cherlow (1981) for an overview of this literature).

An important development concerned the use of the wage rate in valuing time in recreation demand models. This apparently arose from Cesario and Knetsch (1970) and Cesario (1976) who used a fixed fraction of the wage rate to value time. This method assumes that leisure (or recreation) time can be substituted for work at some constant wage. McConnell (1985) questions this assumption, noting that institutions and recreation behaviour argue against it. For example, income taxes create differences between before and after tax wage rates and these rates vary considerably among individuals. With respect to behaviour, recreationists may get utility (or disutility) from work and therefore need to be compensated more (or less) than the wage rate. It is interesting to note that traditional travel cost analyses have ignored these objections, and following Cesario's (1976) notion, have assumed that people get disutility from spending time travelling to recreation sites. This cost has usually been valued at one third of the wage rate based upon Cesario's (1976) recommendations. This assumption has even been incorporated into formal procedures by government agencies used to investigate recreation benefits (e.g. Water Resources Council 1979, 1983).

There are a number of recent articles investigating the value of time. McConnell and Strand (1981) questioned Cesario's wage rate approach, and suggested that time and travel costs could be separate arguments in the demand function. Smith et al. (1983) developed a model where the value of time was determined in part by the wage rate which was in turn predicted by an hedonic price equation. They also included time spent at the site as part of the model. Bockstael, Strand, and Hanemann (1984) provided perhaps the most realistic approach where they included variation in the types of time constraints held by recreationists in a sample. For example, some individuals have flexible working hours, while others do not. As Smith (1989) notes, these studies resulted in the altering of traditional recreation surveys and the specifications used to estimate travel cost demand models.

The issue of what time values to measure: travelling time or on-site time, is also an area of concern for recreation demand estimation. The traditional travel cost model assumes that all trips are homogeneous in length; thus the time requirements are fixed per trip. Time spent travelling and on-site are not treated as choice variables in the model. Cesario's method of using wage rates and many of the subsequent empirical studies considered only the time spent travelling and not the time spent recreating, thus valuing it at zero. A number of economists were concerned with this restrictive assumption and strove to develop a travel cost model with different under-pinnings. Wilman (1980) for example, developed a utility-based model with goods and services requiring time, those not requiring time, and two measures of recreation site use: the number of visits to a site of a given length, and the number of round trips to the site. She showed that travel time could be valued as "travel time saved" while on-site time could be valued in terms of its scarcity value.

Smith et al. (1983) developed a different model of consumer choice where recreationists face multiple types of time constraints. They extended this concept directly to the types of sites available for recreation suggesting that some sites could be "local" in nature while others could be "national". The former could serve the immediate region and time constraints here would be viewed differently than time constraints for the latter types of sites. The relevant opportunity costs of travel and on-site time for these two types of sites can be expected to be different.

The most recent developments which consider the inclusion of time spent at the site involve the repackaging model of Wilman (1987) and Kealy and Bishop's (1986) model which uses days spent on site rather than visits as the dependent variable. This latter study supported the inclusion of on-site time as an independent variable in the travel cost demand model, and is appealing because it was derived from a specified utility function. This approach allowed some variation in the choice of length of trips rather than the more restrictive traditional model.

2.4 The Issue of Demand Heterogeneity in Travel Cost Models

An important assumption in the traditional travel cost method is that all sampled individuals in a TCM study have the same demand parameters. This assumption arises due to the fact that travel cost modelling is essentially applied demand analysis where each consumer is assumed to have the same demand function and demand parameters. The behavioural choices of each individual recreationist in the sample used in the estimation of a typical TCM can be thought of as individual choices by one "large" consumer.

To investigate this assumption further it is necessary to note that the objective of the traditional TCM is to obtain an estimate of the economic benefits derived from recreating at a particular site.[3] Since the method was devised to provide welfare measures, it utilizes travel cost demand equations which must be linked to utility maximization, an integral component necessary in employing welfare theory to measure benefits. This linkage provides the foundation for many restrictive assumptions that describe recreation behaviour in a travel cost demand model. Thus, the most important assumptions in the traditional TCM are that each recreationist can be represented by the same utility function, and that each is operating to maximize utility subject to the same time and income constraints.

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[3] It is worth emphasizing here that the traditional single site model is designed to obtain site values, not changes in benefits that arise when conditions at the site vary. The need to pursue this latter line of enquiry led to developments in the TCM including: the hedonic TCM (Brown and Mendelsohn 1984), the varying parameter model (Smith and Desvouges 1986), and random utility models (Smith 1989).

2.5 Testing the Traditional Travel Cost Model

The preceding discussion of the travel cost method, although brief, identifies that the approach used by many researchers to estimate recreation benefits involves representing recreation behaviour with a simple model. In this process a number of very restrictive and unrealistic assumptions are made regarding behaviour. The identification of these assumptions has been a revelation to many workers in the field (Pers. Obser.) and has led to a reconsideration of the TCM as a "standard" in recreation benefit estimation.

The assumption of utility maximization in the traditional travel cost model has not been tested empirically. Adamowicz (1988) and Adamowicz and Graham-Tomasi (1991), however, have tested this assumption on a related level. They investigated the consistency of utility maximization with the site choices made by recreationists on an individual level. Their approach was to assume that each individual trip by a hunter to a hunting site was made at prices including travel costs, time costs, and related recreation expenditures. Using nonparametric demand analysis, they investigated the set of choices made by each hunter over the course of a hunting season. They were able to show that the discrete choices made by hunters in their sample were generally consistent with a maintained hypothesis of utility maximization. However, their approach, although theoretically sound, does not provide a test of the traditional TCM. This test requires that the choices made by the entire sample of recreationists be considered as if they were made by one consumer, and that the entire set of choices be analyzed simultaneously for consistency with utility maximization. In other words, one must test to see if each recreationist in a set of data has the same utility function, and that they are exhibiting maximizing behaviour.

A related question involves whether recreationists can be arranged into sub-groups based upon some preconceived notion of homogeneous preferences in order to account for the problem of demand heterogeneity. The traditional method of accounting for heterogeneity in demand analysis is to incorporate shift variables such as income, age, or some other socioeconomic variable in the demand function; or to include interaction terms between travel costs and socioeconomic variables (Fletcher et al. 1990). However, the inclusion of many demand shift variables has not generally been supported using statistical criteria in the estimation of many travel cost models (e.g. Gum and Martin 1975). Moreover, these approaches still impose the condition that all individual demands are essentially the same (Fletcher et al. 1990).

An alternative is to stratify a data set by some socioeconomic variable(s) and to estimate demand parameters for each stratum separately. However, selecting the correct socioeconomic variable and determining the appropriate number of categories of the variable is a key to success in using this approach. This method was suggested by Adamowicz and Graham-Tomasi (1989). They stratified a sample of recreation data by a number of socioeconomic variables, and using non-parametric demand analysis to investigate homogeneity of preferences in each stratum, determined that income was a "reasonable" variable to stratify on.

This thesis provides a test of the traditional TCM using nonparametric demand methods and investigates a number of the issues described above. The traditional TCM is first tested by considering the choices made by an individual recreationist **over a recreation season** as a consumption bundle. By amalgamating these bundles over a number of recreationists, and assuming these are the choices made by one consumer, the hypothesis of utility maximization can be tested. In other words, by maintaining an hypothesis that individuals are rational in the sense that their behaviour is consistent with a utility maximization model, the travel cost method is tested to see if the choices generated by the individuals are consistent with the utility function implied by the travel cost model.

A second set of tests involves assessing the consistency of various prices including values of time in the travel cost model. These tests involve a maintained hypothesis of utility maximization. The time values used are wage rates determined using a number of socioeconomic variables commonly collected in recreation surveys. Several fractions of these wage rates are also assessed.

The third set of tests involves an evaluation of various stratifications of recreation data to account for demand heterogeneity. The tests of these stratifications will also involve investigations of the value of time.

Finally, the issue of separability with respect to recreation sites will be addressed by testing the consistency of the utility maximization hypothesis in recreation data from separate groups of sites. The groups of sites were not chosen at random, but were determined using criteria which would seem to influence site choice by a recreationist.

The remainder of this volume summarizes nonparametric demand theory and methodology, its application to recreational site choice by a sample of Bighorn Sheep hunters in Alberta, and results of a number of tests which explore issues in the application of travel cost methodology to recreation site choice.

3.0 NONPARAMETRIC DEMAND ANALYSIS

3.1 The Theory of Revealed Preference

Economists usually model consumer behaviour based upon a preference structure or ordering for various commodities. The most common theoretical structure for investigating consumer choices is to assume the existence of a utility function which imposes a particular structure or form on the choice of consumption bundles. The actual preferences held by consumers are not readily observable, however, so economists can only observe demand behaviour which involves observations of actual choices by consumers. In other words, unobservable preferences generate observable choices. The theory of revealed preference builds on this idea of using observed behaviour to approximate utility functions. It was first proposed by Samuelson (1938). The review of the theory that follows summarizes the discussions by Richter (1987), Varian (1982, 1987a, 1987b), and Adamowicz and Graham-Tomasi (1991).

Samuelson suggested that the observed choices by individual consumers could be used to investigate maximizing behaviour based on principles of rationality. For example, if a bundle of goods y could have been purchased by an individual within his budget when he was observed to purchase x, then that individual has revealed a preference for x over y. This individual's preference should be "consistent" in that given that x and y are obtainable and affordable under some other budget, y would not be chosen over x. From this information a utility function can be approximated. This idea led to the development of revealed preference tests which take the observed choices and investigate whether these choices are consistent in the sense of maximizing a preference relation.

In order to "rationalize" choice behaviour, revealed preference theory assumes a consumption set X of consumption vectors x, a price vector p, and a family B of budgets with elements b (Richter 1987). Each element b can be defined as: $b=\{x: x \in X \text{ and } px \leq m\}$, where $m \geq 0$ and represents income. A set of bundles, h, can be chosen from b, so that h(b) contains all possible bundles which could be chosen by a consumer subject to that particular budget b. The theory uses as a construct the idea that a rational consumer maximizes a **binary** preference relation R. This R denotes that one particular bundle of goods is preferred over another. Thus rationality is defined by there being an R such that: $h(b)=\{x: x \in X \text{ and } \forall y \in b, xRy\}$ (Richter 1987).

Having defined R as a preference relation, the next step is to investigate potential properties of R. One possibility is the directly revealed preferred relation. This particular relation identifies that x is directly revealed preferred to y if x was chosen when y, although affordable and a different bundle than x, could have been chosen. This relation is used to define the Weak Axiom of Revealed Preference (WARP) (Samuelson 1950). It can be formally stated by using R^0 to denote the directly revealed preferred relation: xR^0y if and only if there exists $b \in B$ such that $x \in h(b)$ and $py \leq px$ with $x \neq y$ and $y \in X$. If the WARP holds, then xR^0y and x will be directly revealed preferred to y under any budget. In other words the WARP is xR^0y and implies not yR^0x.

The WARP is a tool that can be used to investigate the economic rationality of observed choices of consumers (Varian 1987b). Figure 1.1 provides an example of a violation of the WARP in two good space. Under budget A the consumer chose x when y was affordable. Under budget B the consumer chose y when x was affordable. In this case the

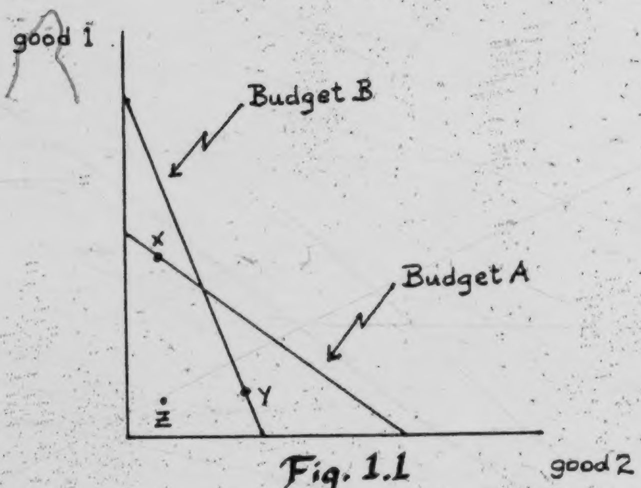
good 1
Budget B
x
Budget A
Y
z
good 2

Fig. 1.1

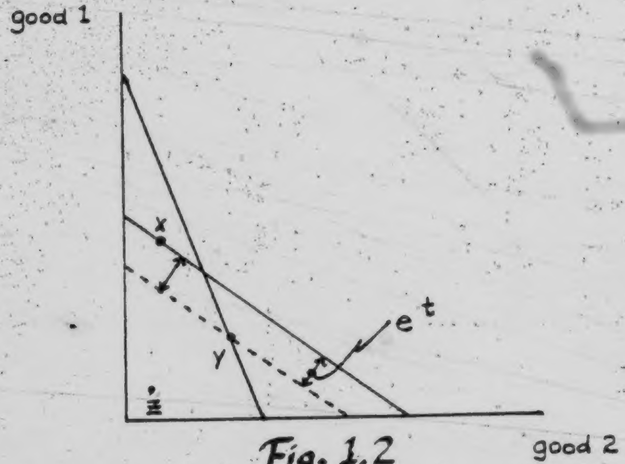
good 1
x
e^t
Y
z
good 2

Fig. 1.2

Figure 1. An example of a violation of WARP (Fig. 1.1) and of a perturbation of a budget used in revealed preference tests (Fig. 1.2). In Figure 1.1 a violation of WARP is shown. Under budget A bundle X was preferred over bundle Y. Under budget B, Y was preferred despite X being affordable. In Figure 1.2 budget A has been moved by an amount e^t. This perturbation results in a decrease of expenditure necessary to make Y a maximizing choice.

consumer has violated the WARP and is not exhibiting rational maximizing behaviour.

The WARP describes conditions where only two choices can be investigated for consistent maximizing behaviour. An important additional condition for consistency in choice behaviour is transitivity. Houthakker (1950) proposed that the WARP was not sufficient to allow transitivity (but see Sen 1973). He proposed a relation later called the Strong Axiom of Revealed Preference (SARP) by Samuelson (1950) which contains stronger conditions on preferences than the WARP. To illustrate the SARP consider x revealed preferred to y, and y revealed preferred to z, then z will never be revealed preferred to x. In this example the revealed preferred relation can be direct, as described above, or indirect which refers to a situation where an actual observation of a bundle being chosen over another was not involved but could be inferred from other preference relations and budgets (e.g. see Figure 1.1, bundle z). The SARP thus implies a transitive closure to the preference relation R^0 (Varian 1982).

Some economists have developed other axioms that are basically modifications of the SARP. One particular axiom of interest is the generalized axiom of revealed preference (GARP) proposed by Varian (1982). This axiom involves the **strictly** directly revealed preferred relation, P_0. To illustrate this, x_1 is strictly directly revealed preferred to x_2, written $x_1P^0x_2$, if $p_1x_1>p_1x_2$. The GARP is defined as: x_1Rx_2 implies not $x_2P^0x_1$. Note that there is not the requirement for $x_1 \neq x_2$. The GARP differs from the SARP in that it allows multi-valued demands, or the existence of "flat spots" on indifference curves. Varian's theoretical work on the GARP is of interest here because he provides tests which can be used to investigate consumer choice behaviour with consistency with the GARP. Varian (1982) has termed the testing of choice behaviour for consistency with revealed preference axioms, nonparametric demand analysis.

Varian (1985) describes a number of tests that involve investigating a consumer's utility function as having a particular form. For example, he develops a useful criterion of separability by showing theoretically that an entire set of choices, representing a macro utility function, must be consistent with the GARP, and that a subset of this data, which represents a sub-utility function, must also be consistent with the GARP. If these conditions are met, then the utility function is weakly separable into sub-utility functions. This example essentially identifies the nature of nonparametric demand analysis. The tests involved in nonparametric demand analysis are described in the next section.

3.2 Testing Observed Choice Behaviour for Rationality

The SARP is a necessary and sufficient condition for the demonstration of rationality in consumer behaviour. Matzkin and Richter (1987) show that choice behaviour that is consistent with the SARP is all that is required for the identification of a concave utility function. Varian (1982) identifies that consistency of choices with the GARP supports a concave utility function. Therefore, examination of a set of consumer choice data for violations of the SARP or GARP may provide some idea of the consistency of that data with the underlying theory of economic maximizing behaviour.[4]

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[4] This examination was enhanced through the work of Varian (1982) who provided algorithms for computing the transitive closure of directly revealed preferred relations.

One way to examine data for consistency with the axioms of revealed preference is to utilize the inequalities proposed by Varian (1987a) in his definitions of revealed preference relations. Varian writes (p. 2): "An observation x_i is directly revealed preferred to a bundle x (written $x_i R^0 x$) if $p_i x_i \geq p_i x$. An observation is revealed preferred to a bundle x (written $x_i R x$) if there is some sequence such that $x_i R^0 x_j \ldots . x_k R^0 x$. A set of data $(p_i x_i)$, i=1,....n satisfies the GARP if $x_i R x_j$ implies $p_j x_j \leq p_j x_i$." A test for the WARP using the inequality for the directly revealed preferred relation above is illustrated in a hypothetical set of data shown in Figure 2a. These data, taken from Varian (1987b), reflect a consumer in three choice occasions, involving two goods, x_1 and x_2, at two prices, p_1 and p_2. Calculating the inequalities (Figure 2b) identifies that the third bundle chosen is clearly preferred to the other two when it is affordable. However, the WARP was violated by the consumer in considering bundles 1 and 2 with the prices he faced in observations 1 and 2. On the first choice occasion bundle 1 was directly revealed preferred to bundle 2, while on the second choice occasion bundle 2 was directly revealed preferred to bundle 1, despite being affordable. Figure 2c identifies in graphic form the consumer's budgets and choices on each of the three choice occasions. This graph clearly identifies the violation of the WARP and is consistent with the similar illustration of a WARP violation in Figure 1.

This example of identifying a WARP violation is relatively easy to follow. Testing for the more sophisticated revealed preference relations and their associated axioms, SARP and GARP, require computer programs to compute transitive closures. The testing of consumer behaviour for consistency with these more restrictive axioms are more powerful in the investigation of rational choice behaviour. The

Figure 2. A numerical example of the determination of a violation of the WARP (adapted from Varian 1987b). **A**: a set of data from a consumer who faced three choice occasions, involving two goods at three different sets of prices. **B**: determination of the preferred bundles in each of the three choice occasions. Note that the consumer violated the WARP during the first and second choices; he chose X^1 when X^2 was affordable, then chose X^2 when X^1 was affordable. **C**: A graph of the budgets and chosen bundles in each of the three choice occasions.

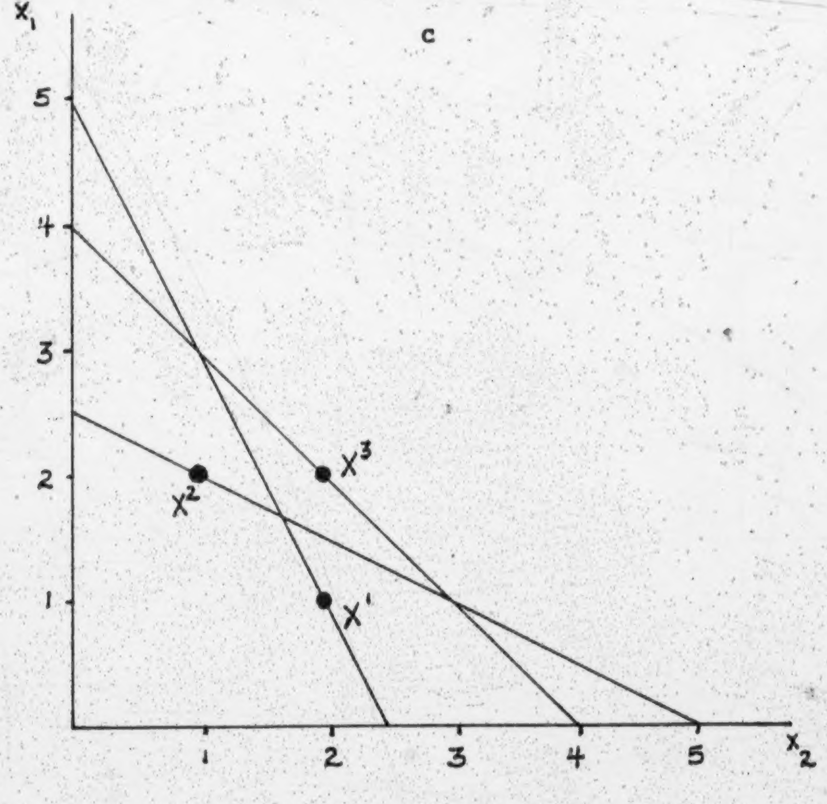
A

Choice Occasion	Prices		Goods		Costs
	p_1	p_2	x_1	x_2	
1:(P^1X^1)	1	2	1	2	5
2:(P^2X^2)	2	1	2	1	5
3:(P^3X^3)	1	1	2	2	4

B

Prices 1 **Demand 1**	$P^1X^1 \geq P^1X^2$	$5 \geq 4$	$X^1R^0X^2$
	$P^1X^1 \geq P^1X^3$	$5 \geq 6$	X^3 not affordable
Prices 2 **Demand 2**	$P^2X^2 \geq P^2X^1$	$5 \geq 4$	$X^2R^0X^1$
	$P^2X^2 \geq P^2X^3$	$5 \geq 6$	X^3 not affordable
Prices 3 **Demand 3**	$P^3X^3 \geq P^3X^1$	$4 \geq 3$	$X^3R^0X^1$
	$P^3X^3 \geq P^3X^2$	$4 \geq 3$	$X^3R^0X^2$

C



remainder of this chapter will describe procedures developed for testing for violations of the GARP. The GARP is similar to SARP in that it requires transitive closures of relations. However, GARP differs in that it is compatible with multi-valued demand functions. Varian (1982) shows that SARP implies GARP but not vice versa. However, there are likely very few cases where the GARP will be satisfied while the SARP is not due to the limited size of most data sets (e.g. see Adamowicz and Graham-Tomasi 1991). Thus, testing a set of data for either of these axioms will be similar and will reveal a powerful test of consumer behaviour.

The examination of data for violations of revealed preference axioms can be complicated by the fact that measurement errors can exist in data sets of choice behaviour gathered from a consumer. These data may exhibit violations while the unobserved true preference structure held by the consumer is consistent with revealed preference axioms. This possibility has been studied extensively by Varian (1985) and Tsur (1989) who investigate the question: Are violations of the revealed preference axioms noted in observed choice data sets significant?

Varian (1987a) suggested that one could measure the severity of the violations, or in his words: "what is meant by maximizing behaviour?" Varian approached this problem by suggesting that the "size" of the violation be measured. Size in this context refers to the amount a consumer's budget would have to be perturbed in order to allow his/her choices to be consistent with GARP. Minimizing the perturbation budgets are subjected to in order to satisfy the SARP reveals a measure of the severity of violations. Figure 1.1 illustrates an example of the perturbation of a budget to remove a violation of WARP. The amount the budget had to be moved toward the origin is the degree or size of the violation.

In formal terms, consider demand data (p^t,x^t) where p^t is a price vector and x^t a vector of quantities for $t=(1,....,T)$. Also consider a given set of numbers e^t, $t=(1,....,T)$, and $0 \leq e^t \leq 1$. Varian redefines the direct revealed preferred relation as $x^1 R_e x^2$ if and only if $e^1 p^1 x^1 \geq p^1 x^2$, and further defines R_e as the transitive closure of this relation. If $e^t=1$, the direct revealed preferred relation holds. However, if $e^t=0$, the relation is invalid. Thus e^t, which is a scalar ranging from 0 to 1, could be considered as the amount the potential expenditure on a bundle x^2 must drop before it is thought worse than the observed bundle x^1. Varian referred to these e^t's as efficiency indices.

Efficiency indices can be used to characterize a set of data as consistent with the axioms of rationality (Varian 1987a). This characterization involves choosing a set of e^t's that are as close as possible to 1 and which remove violations of the axioms. Since SARP implies WARP, one needs only to investigate violations of SARP. The closer the indices are to 1 the closer the observed data are to maximizing choices. Alternatively the closer they are to 0 the greater the chance that the data are not maximizing choices.

Given a set of data (p^t,x^t), however, there are two ways to test for revealed preference conditions. The first involves finding a single e^t that when applied to all observations, removes violations of SARP. Varian claims that this method is easier computationally and describes a binary search method for estimating e^t. This involves starting with $e^t=1$, testing for violations, and if they occur, choosing a smaller value for e^t. This process continues until violations do not occur. At that e^t, the actual single efficiency index has been found. This method will be referred to as the **Single Index Test**.

An example of the single efficiency index is shown in Figure 3. Using the choice data set in Figure 2a, a computer program was used to perform the binary search used to calculate e^t. An efficiency index of 0.800 was generated by this process. This value indicates that one must reduce the consumer's budget by one fifth (i.e. multiplied by 0.800) in order to make bundle 2 a maximizing choice under the prices he faced when choosing bundle 1. This shift in the budget is shown by the dashed line in Figure 3. In the same spirit, the budget must be reduced by the same amount in order to make bundle 1 a maximizing choice under the prices the consumer faced in choosing bundle 2. Thus the value of 0.800 indicates how "badly" the consumer violated WARP in this case.

The concern in using this method to measure the severity of violations of the revealed preference axioms is that one can only determine if one set of data are "better" than another. In other words, the data set with the index closest to 1 is the better set of maximizing choices. What is required is a test which can provide a goodness-of-fit of revealed preference conditions. A number of these have been proposed (e.g. Varian 1985; Epstein and Yatchew 1983) but pose substantial computational effort. However, Tsur (1989) has recently proposed a test which does not require a similar degree of effort.

Tsur (1989) uses what Varian (1987a) calls the **Multiple Index Method** and provides an approximate test of the significance of violations. In this method e^t is calculated for every observation in the data set. After every observa-

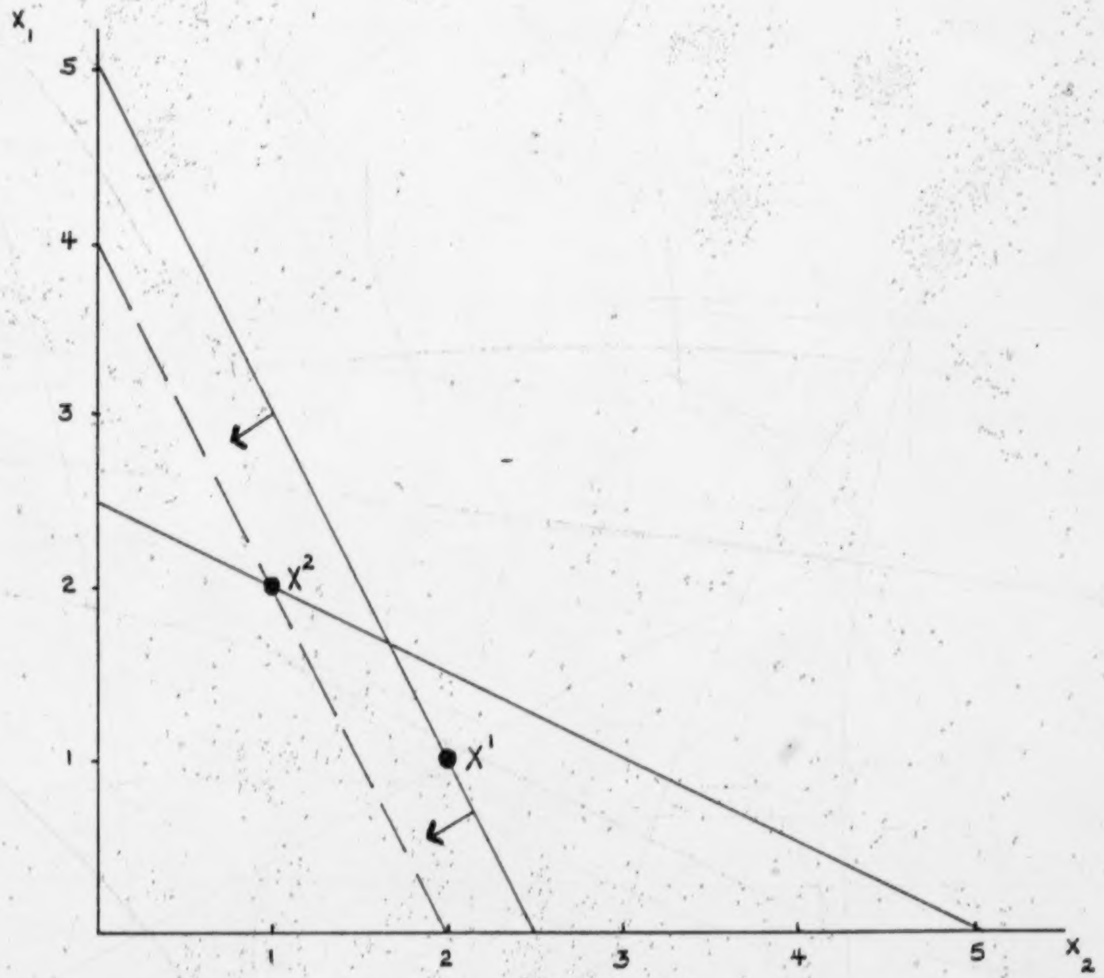


Figure 3. An graphical example of the single index test using the choice data presented in Figure 2. Recall that the bundles, X^1 and X^2), were found to be inconsistent with the WARP. The budget for X^1 was perturbed using Varian's test; the e^t was found to be 0.800. This means that the budget had to be reduced by multiplying the prices by this index value. This results in both of the bundles being consistent with the axiom.

tion has been corrected (ie. the budget perturbed) for violations a vector of e^t's results, each element of which corresponds to an individual observation in the data. Tsur's test maintains an assumption of normally distributed errors and uses the error or perturbation vector to construct ρ, a single value that characterizes the vector in a severity context. It is calculated using the following formula:

$$\rho=\sum_{t=1}^{n}\frac{[\log e^{t}]^{2}}{n}$$

This value is then compared to the variance of the log of actual expenditures. If ρ is greater than the variance of the log of actual expenditures, then the violations are significant. Tsur's method tests the hypothesis that the observed data are consistent with SARP. Thus, this method investigates if the violations in the observed data are due to measurement errors or if the true underlying structure of the data violate SARP.

Tsur's test is approximate in that it assumes a parametric structure (i.e. a normal distribution) for the distribution of errors. This assumption is inconsistent with the fundamental proposition in nonparametric demand analysis, that no a priori structure is to be imposed on the preferences underlying observed choice behaviour. However, Tsur (1990) has recently developed procedures to test GARP utilizing no parametric assumptions on the distribution of errors. He shows that the ρ derived from the parametric form of his test is very close to the ρ derived from the distribution free test. This result lends support for utilizing Tsur's (1989) multiple index test in applied economic work.

Since Tsur's test is an approximation of significance, a number of other outputs in addition to the multiple efficiency index should be used to characterize data as consistent with SARP. These are the number of individual bundles violating SARP, and the mean error, which is an additional calculation indicating the severity of each of the individual violations in the data set. The multiple index routine can determine the number of violations of SARP. This involves searching the perturbation vector (i.e. the vector of e^t's) for occurrences of $e^t<1$. The number of these occurrences reveals the number of violations. The severity or error of each violation can be estimated by taking the corresponding element e^t of the perturbation vector, and calculating $(1-e^t)$. The average of these individual $(1-e^t)$'s is the mean error and provides an additional indication of the degree of violation of SARP. The rationale here is that since $0 \leq e^t \leq 1$, and $e^t=1$ is consistent with SARP, then $(1-e^t)$ provides an indication of the degree of the violation of an individual consumption bundle. Averaging these over all observations in a data set will therefore indicate the severity of these violations.

The nonparametric procedures proposed by Tsur (1989) and Varian (1987a) are used in this thesis to investigate the traditional TCM. These nonparametric procedures are used to test if the recreation choices used in a TCM were made by consumers maximizing a preference relation. A number of outputs from these tests are used to investigate maximizing behaviour. These are summarized in Table 1. The first is the single index value. This index reveals the amount each consumer's budget has to be perturbed in order to make the entire set of choices consistent with the GARP (or SARP). The second is Tsur's modification of the multiple index, ρ, and its comparison to the variance of the log of expenditures (Var). Thus, according to Tsur, where

ρ<Var, the choices are consistent with economic maximizing behaviour. Because this an approximate test, some other measures are calculated. These are the number of individual choices in the sample that violate the axioms of choice, and the mean of the individual errors. In general, in comparing sets of data for consistency with the axioms of revealed preference, the one with fewest violations of the axioms is more consistent. Similarly, the choices with the smallest mean error (derived from Tsur's test) should also be more consistent. When the four measures described in Table 1 are considered together in an analysis of choice behaviour, they should hopefully provide some indication of the consistency of preferences with the axioms of choice.

Table 1. A Summary of Various Measures Used in this Study to Investigate the Consistency of some Recreational Choices with the Axioms of Choice.

Measure of Consistency	Explanation
Single Index Value (e^t)	This index is the amount all budgets in a set of data have to be multiplied by to make the complete set of choices consistent with SARP. It is a scalar variable that ranges from 0 to 1. Values of 1 represent complete consistency with the axioms of choice, while inconsistency increases as the values tend to zero.
Tsur's Test - ρ>Var	Tsur's test involves calculating an index (e^t) for each individual observation in a set of choices. The test relates ρ, a single number representing all of these individual values, to the log of the variance of actual expenditures. If the perturbation of each of the budgets is greater than the variation inherent in actual expenditures, then the choices are not consistent with SARP.
Number (%) of Bundles Violating SARP	This measure provides the number of individual violations of SARP before any perturbation of budgets is performed. In other words, it is the number of individual budgets that have to be perturbed. The percentage provides an indication of the number of budgets in a sample of budgets that must be adjusted.
Mean Error of Individual Violations	This measure is derived by subtracting each individual e^t from 1, and calculating the mean of these values. The subtraction essentially reverses the direction of severity of a violation so that a value of 0 represents perfect consistency; and severity increases as values tend to 1. Therefore, the smaller the mean error, the more consistent a data set is with the axioms.

4.0 DATA AND METHODS USED TO TEST THE TRADITIONAL TRAVEL COST MODEL

Use of the travel cost model requires particular information on the trips recreationists took to one or more sites, the time they spent at the site(s), and various characteristics of the individual recreationists. The construction of a multi-site model appropriate for investigating the validity of the approach also involves choosing a recreation activity with a well-defined choice set of sites, and the ability to estimate travel distances to these sites from the origins of recreationists. In this study such a data set was used, and matrices containing vectors of the numbers of trips to a finite set of sites by individuals and vectors with the associated prices including travel costs, travel time costs, and on-site recreation time costs were constructed. These reflected price-quantity pairs that when grouped over individuals, represented a commodity bundle that could be used in nonparametric tests of the axioms of choice. Thus, at the outset, the implied assumption in the traditional TCM of the numbers of trips being chosen by an individual at the beginning of the season is invoked and can be one of the elements of the method under investigation. Furthermore, the validity of various issues surrounding the TCM can be investigated using the revealed preference tests. Under a maintained hypothesis of rationality, for example, a number of tests of the data can be made using adjustments of the price vectors. In this study these adjustments involved various considerations of the value of time in the model.

Data used in this thesis were collected from recreational Bighorn Sheep hunters in Alberta. This recreational activity represents a good example of an activity with a limited choice set of sites due to strict government regulation of hunting, and due to the limited distribution of the Bighorn Sheep numbers in Alberta. These data were collected by Adamowicz (1983) from 623 Albertans who held general licences during the 1981 hunting season. These licenses can be purchased at nominal fees and their distribution is not limited through a lottery process as are some other big game licenses in the province. From this set of data, 226 individual hunters provided sufficient information to be used for the present study. Table 2 presents a summary of their socioeconomic characteristics.

The investigation of individual preferences in this study involved describing the numbers of trips taken by each hunter to various hunting sites over the entire hunting season as the set of choices of goods (i.e. a consumption bundle), and the out-of-pocket travel costs, travel time costs, and on-site recreation time costs as the price vector.

The use of trips to sites at relevant prices equal to travel costs as a consumption bundle assumes that the number of trips taken hunting is determined at the beginning of the hunting season. The choice occasions involve selecting the correct combination of "purchases" of trips to various sites to maximize a preference ordering. Therefore, the tests of rationality of the observed choices involved comparing the observed consumption bundle of one hunter at the prices he faced with the observed consumption bundles of other hunters at different prices.

The original hunter data included the numbers of trips to 27 different geographical areas called Wildlife Management Units (WMU's). These areas are established by government biologists and are used to regulate access by humans to the sheep and other game species. In order to make the

Table 2. Some Socioeconomic Characteristics of the Sample of Bighorn Sheep Hunters Used to Investigate the Travel Cost Model.

Socioeconomic Characteristic	Mean, % or Median	Standard Deviation
Age (Years)	35.02	10.90
Sex (Percent Male)	98.6	
Income (Median)	$31,123	
Education (Years)	12.70	2.77
Big Game Hunting Experience (Years)	17.68	11.20

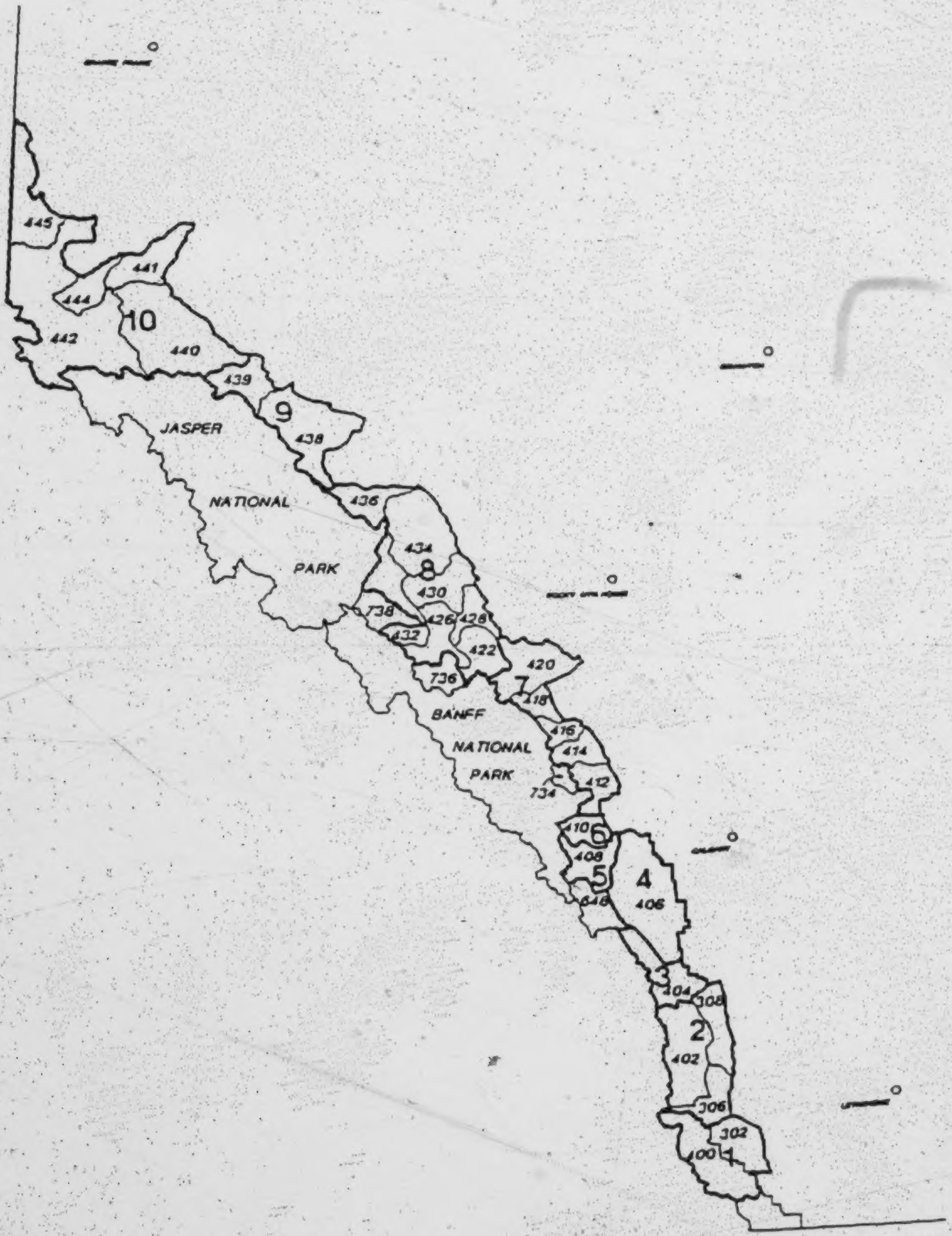
analysis tractable, and to reflect possible similarities in certain hunting quality attributes of the WMU's, the 27 areas were aggregated into 10 "sites". These sites are illustrated in Figure 4.

Two of these sites merit comment. Site 6 is an area restricted to individuals using archery in hunting big game species. It is established through hunting regulations and bow hunting is monitored by enforcement officers. Site 10 largely represents the Willmore Wilderness, an area with little or no developed access to the habitats where sheep and other game species are found. These two sites are mentioned here because of their obvious difference, through regulation and access, to the other eight sites in the study.

Having established the set of x^t's (goods) as the number of trips taken to the 10 sites during the season, the next step was to establish the relevant prices, p^t, faced by each hunter in selecting sites in which to hunt. As described in Section 2.0, the total price of a recreational trip consists of travel costs and time costs. In this study the total price (P) consisted of:

$$P = TCOST + (TTIME \times w) + (STIME \times w),$$

where TCOST represents the "out-of-pocket" costs of return travel to the site including fuel and other vehicle expenses, but excluding other costs incurred during travel such as food and accommodation; TTIME represents the estimated number of hours spent travelling; STIME represents the time (in hours) spent at the site; and w represents an individual's hourly wage rate. Although many travel cost studies utilize TTIME only in measuring the opportunity cost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648
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402
306
302
400
1

Figure 4. A map illustrating the ten hunting sites used in this study to describe site choices by sheep hunters.

of time, a number of researchers have shown that ignoring the on-site time is invalid (e.g. Wilman 1980). In this study the values of TTIME and TCOST are dependent on the distance between origins and sites. Therefore, incorporating TTIME with TCOST simply shifts the budget lines by an amount equal to the proportion of an individual's wage rate. The magnitude of STIME, however, is not directly dependent on distance, and incorporating it results in changing the slope of budget lines[5].

The travel distance component of the cost was estimated by determining the shortest round trip distance in kilometres between each hunter's origin or home and the 10 hunting sites. These were estimated using charts and maps from Alberta Transportation (see Coyne 1990 for details). Table 3 illustrates the variability inherent in these distances faced by sheep hunters. For example, hunters faced round trip distances between their homes and the closest point of entry to sites which ranged from 7 to 1388 kilometres. The mean distances ranged from about 260 to approximately 600 kilometres. The data set includes information on 423 actual trips made by the hunters. Site 1 was the most frequently visited site, while site 6 was the least visited (Table 3).

Travel costs were calculated by multiplying these distances by a mileage charge of 18 cents per kilometre which represents the estimated costs of purchasing fuel and vehicle maintenance services on a unit distance basis in 1981 (Coyne 1990). Table 3 provides a summary of the magni-

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[5] It would be useful to separate travel time and travel cost from the on-site time and examine only these two elements. However, as described above use of the revealed preference tests are limited by the need to change the slopes of budget lines in investigating prices.

Table 3. A Summary of Information on the Trips, Distances and Out-Of-Pocket Costs of Travelling between Origins of the Hunters and the Ten Hunting Sites.

NUMBER OF TRIPS (N=423) BY SITE FOR ALL HUNTERS

	1	2	3	4	5	6	7	8	9	10
No. Trips	94	88	32	33	43	21	38	36	12	26

ROUND TRIP DISTANCE FROM A HUNTER'S HOME TO THE SITE BY SITE

	1	2	3	4	5	6	7	8	9	10
Mean	316.6	261.4	265.1	236.5	255.4	270.3	282.4	367.1	472.1	601.6
S.D.	246.4	212.9	194.0	178.5	169.1	157.2	148.0	141.4	179.2	220.7
Maximum	1388	1278	1222	1111	1167	1056	1056	889	778	944
Minimum	18	16	14	12	7	9	14	32	55	20

ROUND TRIP OUT-OF-POCKET TRAVEL COSTS BY SITE

	1	2	3	4	5	6	7	8	9	10
Mean	56.09	47.05	47.72	42.57	45.97	48.65	50.84	66.08	84.97	108.29
S.D.	44.36	38.33	34.93	32.12	30.43	28.29	26.64	25.45	32.25	39.74
Maximum	250.0	230.0	220.0	220.0	210.0	190.0	190.0	160.0	140.0	170.0
Minimum	3.20	2.90	2.50	2.20	1.30	1.60	2.60	5.30	10.00	3.60

tudes and variability of these costs. Considering the entire sample, on average the most expensive site to visit was site 10, which cost a hunter $108.29 per trip. The most inexpensive site was site 4 which cost on average $42.57. The most expensive travel cost faced by an individual in the sample, however, was $250.00 while the cheapest was $1.30.

Estimates of the time costs faced by the hunters in this study consisted of three components: the number of hours spent travelling, the number of hours spent on-site, and hourly wage rates. Hourly wage rates were estimated using income and occupation data gathered from the 226 hunters during the survey. Household income was collected directly from the hunters using a categorical variable (Table 4). Wage rates were calculated from these data using estimates of the average number of hours worked during 1981 from Statistics Canada (1981a). The use of household income to calculate wage rates may be a problem because one cannot relate the rate to the individual respondent who hunts in the household. Thus, a second wage rate was calculated based upon the individual's occupation reported in the survey. Since all hunters in the sample were from Alberta, occupations were combined into various categories, and review of hours worked from Statistics Canada (1981b) and salary data from the Alberta Bureau of Statistics (1982) allowed estimates of wage rates to be calculated. These methods allowed an ordinal scale to be created for these wage rates as well (Table 4).

In order to calculate the costs of travel time the approximated hourly wage rates for each of the income and occupation categories (Table 4) were multiplied by the estimated number of hours spent by the hunters travelling between their homes and hunting sites (TTIME). These hours were derived using the distances between origins and sites

Table 4. The Income and Occupation Categories Used in this Study and their Associated Hourly Wage Rates.

Income Category ($)	**Hourly Wage Rate[1] ($)**
2500-17500	6.21
17501-22500	11.63
22501-27500	14.22
27501-32500	16.81
32501-42500	20.68
greater than 42500	25.85

Occupation Category ($)	**Hourly Wage Rate[2] ($)**
Student	0.00
Sales and Service	6.10
Unskilled Labour	7.00
Farming	8.00
Transportation	8.85
Trades	13.00
Management	18.87
Professional	20.68

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1. These wage rates were calculated using the midpoint of these annual salary ranges and assuming each individual worked an average of 40.3 hours per week or 1934.4 hours during the year 1981 (taken from Statistics Canada 1981a)

2. These wage rates were calculated using information from the Government of Alberta's 1981 Pay and Benefits Survey (Alberta Bureau of Statistics 1982).

described above and by assuming an average vehicle speed of 80 kph.

The time spent by individuals at each site (STIME) was collected directly from the hunters through the hunter survey. A question was asked about how many days were spent hunting by the respondent during each trip to the site. These days were converted to hours assuming a day was 8 hours long. The opportunity costs of on-site time were derived by taking the hours and multiplying it by the appropriate individual's wage rate (Table 4). In cases where a hunter did not visit a particular site during the season, an estimate of the on-site time costs he would have faced in choosing that site was derived by taking the mean number of hours he actually spent hunting at all sites during the year and multiplying this by his wage rate.

Other socioeconomic data gathered from the hunters included the number of years of big game hunting experience, sex, age, and the degree of education in years. Years of hunting experience were collected as ratio scale data. These data were combined into an ordinal scale after investigation of the distribution of the information provided. Sex was not considered in this study as nearly all of the hunters were male. Age and education were collected directly from the hunters as ratio scale data (in years). However, these variables are not considered in this study due to their wide variation and analytical time constraints.

To summarize, the entire data set consisted of 423 choices made by 226 recreationists which involved choosing 0-7 trips to each of 10 recreation sites. These choices of where and how many times to go were made by individuals who each faced a unique set of prices consisting of travel costs and the opportunity costs of both travel and on-site time.

If one were to use these data in a traditional travel cost analysis one would regress the number of trips taken by the hunters to any one of the sites, or all of the sites collectively, against price and calculate a demand curve[6]. However, as described above, this assumes that the data set can be considered as 226 choices made by one consumer maximizing a preference structure. Thus testing this assumption involved investigating the entire set of 226 choices collectively for violations of the SARP. This was performed by calculating the multiple index test for the entire data set using Tsur's (1989) method. This test and a routine for the transitive closure of directly revealed preferred relations were calculated on a microcomputer using GAUSS, an econometric matrix programming language (see Appendix 1), and using FORTRAN based programs for later runs.

The multiple index test was also performed on the entire data set to address value of time issues. The price vector was changed by utilizing a different wage rate to calculate the opportunity cost of time. First, the entire data set was tested utilizing an opportunity cost of time equal to zero. This test represents an investigation of the simplest form of the traditional travel cost model where only TCOST is considered and time costs are ignored.

In the second and third sets of tests, wage rates were used to estimate the costs of time based upon the hunter's reported income levels and occupational categories. Two different fractions of the wage rate were considered in using each type of wage rate: the full hourly wage, and a third of this hourly wage. These tests were performed to investigate the possibility of achieving better results using non-zero time values as would be expected from theory. This could have some relevance to incorporating improved methods of using the travel cost model in the analyses of resource utilization policies. The different fractions were utilized in an attempt to support Cesario's (1976) suggestion that one-third of the wage rate should be used in TCMs.

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[6] This is obviously a simplistic approach as one would want to: i) incorporate other variables such as substitute sites and socioeconomic variables; ii) ascertain whether a specific site value is required or if the value of the entire recreational activity is important; and iii) utilize sophisticated limited dependent variable techniques in accounting for zero trips to some sites.

A related set of analyses were undertaken using both the single and multiple index tests, and where relevant, incorporating different time values. These involved stratifying the hunter data set by income, occupational category, and years of experience hunting. The revealed preference tests were performed on each stratum in order to investigate the possibility of homogeneous preference structures among the members of each of the strata. This also has relevance to improving travel cost procedures in analyses of resource policies in that demand analysis may be more accurate if estimation is performed on different strata than on entire samples of data.

Finally, the issue of separability was investigated by testing the compatibility of subsets of the choice set of sites with revealed preference axioms. These tests proceed using the following exposition. Assume the existence of a utility function, γ, operating over all recreation including hunting. Separability can be approached in two ways: 1) there is a sub-utility function operating within γ over the choice sets of sites for recreational sheep hunting, and an examination of grouping the sites in the entire set of available sites may reveal the proper choice set; or, 2) there are relevant sub-utility functions operating over combinations of sites within the entire choice set. The first approach involves a number of sub-utility functions (represented as σ_i, i=1......n) dropping from γ in a horizontal manner as shown below:

Utility Function: **γ(hunting, other recreation)**
↙ **or** ↘
Sub-utility Functions: **σ_1(10 sites)** **σ_2(8 sites)**

In other words, given γ, which combination of sites can be represented by a sub-utility function which provides the relevant choice set for recreational sheep hunting? Testing the sheep hunting data set using this view of separability, thus represents a site choice verification approach.

The second involves thinking vertically from γ as shown below:

γ(hunting, other recreation)
↓
σ_1(10 sites)
↓
σ_2(8 sites).

In this case, one first examines the entire choice set of ten sites to see if this set can be considered a valid sub-utility function. Then one investigates a further partitioning of sites "beneath" the ten that suggest the notion of "sub-sub-utility functions". This approach involves an examination of separability in a traditional economic context.

These approaches were investigated in this thesis by testing two choice sets of sites. Since two sites in the choice set available for sheep hunting were distinct from the other eight due to differences in hunting regulations and access, the choices of trips to these sites were removed from the data set. One choice set thus involved the choices of the remaining eight sites. The second choice set involved the full set cf ten sites. Revealed preference tests were conducted on the restricted dataset and the results were compared to those from the complete 10-site data set. The revealed preference tests utilized here included different values of time.

The results of the tests described above are presented in the next chapter.

5.0 RESULTS

5.1 Testing the Travel Cost Model

The first revealed preference test of the hunter data set involved a multiple index test on the entire sample with the value of time equal to zero. The results of this test are displayed in the first line of Table 5. Of the 226 choices of the sheep hunters, 181 (80%) were violations of SARP. These choices collectively represent a significant violation of SARP in that the variance of the log of actual expenditures is less than ρ (Table 5). The average error of the individual violations was 0.43. This is not close to zero, a value of which represents perfect consistency with the SARP. These results indicate a number of possibilities: 1) that the travel cost model is an incorrect representation of the economic behaviour of these recreationists; 2) that the model is accurate, but the prices used in the analysis are incorrect; 3) that there is significant heterogeneity among recreationists in the sample that is not being accounted for in this travel cost analysis; and 4) that the utility function being tested does not contain the appropriate goods (sites). These possibilities are investigated below.

5.2 Incorporating the Values of Time in the Travel Costs

The other entries in Table 5 provide results of revealed preference tests using four different values of time based on income or occupation. The test results indicate a significant improvement in the consistency of the hunter choices with SARP when these values are included in the prices. A number of observations can be made from these results. First, according to Tsur's test, the violations in

Table 5. Results of the Multiple Index Revealed Preference Tests Applied on the Entire Sample of Hunters using Various Estimates of the Opportunity Costs of Travel and Recreation Time.

Value of Time	Results of Multiple Index Test		Number of Violations of SARP (% Total)	Mean of Individual Errors[1]
	ρ	Var.[2]		Mean
None[3]	1.14	0.94	181 (80)	0.43
Wage rate based on income[4]	0.21	0.84	172 (76)	0.16
One third of income wage rate[4]	0.18	0.72	172 (76)	0.17
Wage rate based on occupation[4]	0.75	1.21	181 (80)	0.30
One third of occupation wage rate[4]	0.70	0.88	180 (80)	0.31

[1] This represents the mean of one minus each individual hunter's error term in the perturbation vector. This error is the minimum amount by which each individual's budget has to be perturbed to be consistent with the SARP.

[2] Refers to the variance of the log of expenditures.

[3] In this test, $\rho > Var$; therefore the choices of hunters were not consistent with SARP and represented a statistically significant violation.

[4] The wage rates used here were taken from Table 1 and applied appropriately to each individual hunter in the estimation of the value of time.

all four attempts to include values of time were insignificant. Second, using the income based wage rate provided better improvement in the consistency of the choices with SARP than using the occupation based wage rate. The tests using income resulted in a greater reduction in violations (from 181 to 172), and much smaller mean errors (from about 0.43 to 0.16). Use of the occupation based values, although resulting in insignificant violations, did not provide a similar degree of improvement (Table 5).

In each of the tests incorporating time values, however, there were a large number of violations of the SARP. Tsur's multiple index test suggests that because $\rho<Var$ the violations, although numerous, are small enough to allow consistency with the axioms of choice. This possibility was investigated briefly by visually inspecting the vectors of individual errors. An example of individual errors from the full income wage rate test in Table 5 is shown in Appendix 2. These inspections revealed that there were still some relatively large errors associated with some individuals in the sample. Thus, despite the mean errors for each test incorporating time values being closer to zero, they may not indicate a relatively high degree of consistency of choice behaviour with the axioms.

Despite these reservations about Tsur's test, the results of incorporating time in the travel cost suggest that when the value of time is considered in the prices the model better represents the hypothesis of economic maximizing behaviour by these sheep hunters. The results also suggest that if time were to be valued using wage rates, income may be a better choice than occupation in the determination of the appropriate rate. One cannot conclude, however, that one third of the wage rate is more appropriate than the full wage rate in valuing time. The test results suggest that using either the full or one-third rate in valuing time with income-determined wages may reflect economic maximizing behaviour in the case of recreational Bighorn Sheep hunters in TCM studies.

5.3 Homogeneity of Preferences Within Sample Subgroups

The next set of tests involved stratifying the sample by various socioeconomic variables in order to investigate homogeneity of preferences within strata. These stratifications involved household income, occupation, and years of experience hunting big game. Both multiple and single index tests were performed on these data. The single index test was calculated in order to provide an additional comparative measure of homogeneity between strata.

The results of the revealed preference tests for income strata are shown in Table 6. Violations of SARP were noted in each of the income categories. The income category \$17,500 to \$22,500 had the fewest violations (7 of 25 choices) and the highest single efficiency index. The highest income category, > \$42,500, had the greatest number of violations (36 of 56 choices), the lowest single efficiency index, and based upon a comparison of ρ and the variance of the log of actual expenditures from the multiple index test, had the highest severity of violations. However, none of the income strata had significant violations according to Tsur's test.

One noteworthy observation is a suggestion that the number and severity of violations increase as income increases. A Spearman rank correlation test of the mean errors yielded an r_s of 0.771 which is significant at the 10% level (Siegel 1954). This correlation may be related to the values of time discussed above in other tests. For

Table 6. Revealed Preference Tests of Bighorn Sheep Hunter Site Choice Stratified by Household Income Incorporating No Values of Time.

Income ($)	Number of Hunters	Single Index Value	Results of Multiple Index Test		Number of Violations of the SARP (% Total)	Mean of Individual Errors[1]
			ρ	Var[2]		
2500 to 17500	26	0.604	0.067	0.839	8 (31)	0.083
17500 to 22500	25	0.826	0.039	0.408	7 (28)	0.075
22500 to 27500	46	0.551	0.252	0.777	28 (61)	0.224
27500 to 32500	38	0.750	0.046	0.989	10 (26)	0.065
32500 to 42500	35	0.493	0.318	1.363	17 (49)	0.208
42500 and up	56	0.446	0.873	1.094	36 (64)	0.357

[1] This represents the mean of one minus each individual's error term in the perturbation vector. This error is the minimum amount by which each individual's budget has to be perturbed to be consistent with the SARP.

[2] Refers to the log of the variance of actual expenditures.

example, stratifying the hunter data by income could be amalgamating hunters with similar values of time in the various strata. This suggestion is investigated further below.

Table 7 provides the results of revealed preference tests on occupation categories. The column of occupational categories is organized in ascending order of average wage rate (see Table 5). The hunting choices of Students, the lowest wage rate category, exhibited complete consistency with the SARP; no violations were noted and thus the single index was 1 and the ρ was 0. However, of the 35 hunting choices in the Professional occupational category, 30 violated the SARP. The single index value was low (0.493), and the average error from the multiple index test was considerably higher than that for any of the other occupational groups. In fact, ρ was greater than the variance of actual expenditures (Table 7) signifying a significant violation of the SARP according to Tsur's test. Other occupational categories, although exhibiting some choices inconsistent with the SARP, did not apparently violate the SARP to a similar degree. Overall, the degree of violation increased as the estimated average occupational wage for those categories shown increased. This may be related to the observation noted above for increasing income levels.

Table 8 displays the results for the hunting choices stratified by years of hunting experience. For this variable, only choices in one experience category, 16 to 20 years, exhibited a significant degree of violation of the SARP. This group was in the middle of the range of categories of experience; 44 of 48 individuals violated the SARP, the single efficiency index was low (0.453), and the average of the errors was over two times the next highest value. A pattern was noted for consistency with the SARP in

Table 7. Revealed Preference Tests of Bighorn Sheep Hunter Site Choice Stratified by Occupation Incorporating No Values of Time. The Occupational Categories are Organized in Ascending Order of Wage.

Category	Number of Hunters	Single Index Test	Multiple Index Test		Number of Violations of the SARP (% Total)	Mean Error[1]
			ρ	Var.[2]		
Student	9	1.000	0.000	0.910	0 (0)	0
Unskilled Labour	29	0.896	0.009	1.350	5 (17)	0.026
Sales/ Service	37	0.813	0.085	0.631	14 (38)	0.118
Farmer	32	0.775	0.147	0.775	10 (31)	0.132
Transportation	8	0.812	0.043	1.190	5 (63)	0.121
Trades	44	0.750	0.019	1.140	14 (32)	0.056
Manager	20	0.551	0.173	0.928	10 (50)	0.203
Professional[3]	35	0.493	1.090	0.726	30 (86)	0.449

[1] This represents the mean of one minus each individual's error term in the perturbation vector. This error is the minimum amount by which each individual's budget has to be perturbed to be consistent with the SARP.

[2] Refers to the log of the variance of actual expenditures.

[3] In this occupation category ρ>Var; therefore the choices of hunters in this group are not consistent with SARP.

Table 8. Revealed Preference Tests of Bighorn Sheep Hunter Site Choice Stratified by Years of Experience Hunting Big Game Incorporating No Values of Time.

Years of Experience	Number of Hunters	Single Index Value	Results of Multiple Index Test		Number of Violations of the SARP (% Total)	Mean Error[1]
			ρ	Var[2]		
0 to 5	22	0.833	0.014	0.850	4 (18)	0.043
6 to 10	38	0.575	0.388	1.070	26 (68)	0.295
11 to 15	49	0.564	0.069	0.706	21 (43)	0.114
16 to 20[3]	48	0.453	1.400	1.120	44 (92)	0.485
21 to 25	29	0.446	0.094	0.557	9 (31)	0.110
26 to 30	20	0.897	0.230	1.230	6 (30)	0.117
31 and up	19	0.812	0.005	1.010	3 (16)	0.024

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[1] This represents the mean of one minus each individual's error term in the perturbation vector. This error is the minimum amount by which each individual's budget has to be perturbed to be consistent with the SARP.

[2] Refers to the variance of the log of actual expenditures.

[3] In this experience group $\rho >$ Var; therefore the choices of hunters in this group are not consistent with SARP.

that the lowest and highest experience categories were the most consistent with the SARP, while those in the middle of the experience range were the most inconsistent.

Finally, the perturbation vectors from the strata with significant violations, the Professional occupational and the 16-20 year experience groups, were matched to the individual hunter and compared to see if a number of the same individuals appeared in each, and if these hunters had high e^t's. The reason for this comparison was to examine if some individual hunter choices were contributing significantly to both of the noted violations of the SARP described above. Only seven hunters were common to each of these socioeconomic groups and there seemed to be no consistency with respect to the magnitude of their corresponding e^t's in each of the groups.

These results support an hypothesis of homogeneous preferences within certain socioeconomic groups. This would prove useful in travel cost demand studies as this information could be used to stratify data, estimate demands separately for each stratum, calculate the benefits derived from recreation sites separately, and then sum these benefits to provide a measure of the total recreational benefits derived. If this process is to be used in applied work, the results reported here suggest that income may be the best variable to stratify on. The question that remains, however, involves the dependence of these findings on the omission of the costs of time in the prices used in the tests.

This question was investigated by performing the tests a number of times on the income and occupation strata; each time incorporating values of time using different wage rates. The results of these are reported in Table 9 for

Table 9. Results of Revealed Preference Tests of Bighorn Sheep Hunter Site Choice Stratified by Income with Various Values of Time Incorporated in the Cost.[1]

Stratum	Wage Rate Used	Single Index Value	Results of Multiple Index Test	
			% Viol.	Mean Error
2500-17500	0	0.604	31	0.080
	1/3	0.964	15	0.010
	Full	0.955	15	0.007
17501-22500	0	0.826	28	0.080
	1/3	0.610	20	0.042
	Full	0.601	20	0.039
22501-27500	0	0.551	61	0.220
	1/3	0.809	52	0.095
	Full	0.833	54	0.101
27501-32500	0	0.750	26	0.070
	1/3	0.834	34	0.047
	Full	0.830	34	0.045
32501-42500	0	0.493	49	0.210
	1/3	0.867	43	0.037
	Full	0.919	43	0.026
> 42500	0	0.446	64	0.360
	1/3	0.715	38	0.068
	Full	0.698	39	0.072

[1] Highlighted rows indicate the "best" wage rate in terms of revealed preference test results (see text for details)

income strata and in Table 10 for occupation strata.

With perhaps the exception of income stratum $17,501-22,500, including the values of time in the prices improved the revealed preference test results. For example, the highest income stratum, which performed the worst in terms of the tests with the value of time equal to zero (Table 9), improved by a notable degree. Using values of time equal to either one-third or the full wage rate for this income group, the single index value rose from 0.446 to about 0.700, the percentage of violations dropped by about one-third, and the mean error declined from about 0.36 to about 0.07 (Table 9). The results of these tests for income strata suggest that values of time must be incorporated into travel cost models estimated on data stratified by income. For some income groups (e.g. > $42500), these test results may be used to indicate what the best wage rate is to estimate these values. These are highlighted in Table 9, and are based upon comparing the lowest mean error, the highest single value index, and the percentage of observations violating the SARP. For other strata, the results indicate a general improvement in results based on incorporating costs of time using some income-based wage.

Similar test results were found for the stratified data set incorporating values of time estimated with various wage rates determined by occupation (Table 10). Indications of homogeneous preferences by the sheep hunters within each occupation stratum improved with positive values of time, With this particular mode of stratification, some indication of an appropriate fraction of the wage rate was determined for some strata. For example, according to Tsur's test, hunter preferences within the professional stratum significantly violated the SARP with values of time equal to 0 (Table 7). However, improvement in consistency with the

Table 10. Results of Revealed Preference Tests of Bighorn Sheep Hunter Site Choice Stratified by Occupation Category with Various Values of Time Incorporated in the Cost. (For an explanation of shading, see footnote in Table 7).

Stratum	Wage Rate Used	Single Index Value	Results of Multiple Index Test	
			% Viol.	Mean Error
Student	0	1.000	0	0
	1/3	1.000	0	0
	Full	1.000	0	0
Unskilled Labour	0	0.896	17	0.026
	1/3	0.888	34	0.058
	Full	0.994	28	0.049
Sales/Service	0	0.813	38	0.118
	1/3	0.976	27	0.036
	Full	0.969	27	0.027
Farmer	0	0.775	31	0.132
	1/3	**0.826**	**16**	**0.025**
	Full	0.806	28	0.031
Transportation	0	0.812	63	0.121
	1/3	0.972	63	0.023
	Full	**0.986**	**63**	**0.013**
Trades	0	0.750	32	0.056
	1/3	0.916	34	0.039
	Full	0.869	36	0.034
Managerial	0	0.551	50	0.203
	1/3	0.874	35	0.037
	Full	**0.926**	**35**	**0.037**
Professional	0	0.493	86	0.449
	1/3	**0.806**	**69**	**0.061**
	Full	0.764	69	0.063

axioms of choice was found when either of the two fractions of the wage rate were used to value time. The results for this group suggest that one-third of the wage rate is the better measure of the value of time based upon the revealed preference test results.

Although the findings on the appropriate fractions of wage rates to use to value time within various socioeconomic strata are highly speculative, they identify a line of future research that may be promising in developing specific procedures in applied uses of the travel cost method. The results on the value of time reported in this thesis, however, suggest that these values are positive and that they must be incorporated into travel cost demand models. Under the maintained hypothesis of rationality that characterizes virtually all applied economic research, failure to account for these values renders the results of travel cost demand models inconsistent with economic theory.

5.4 Tests of Separability in Hunting Site Choice

A test of separability (or choice set structure) was performed by removing 31 individuals from the data set who took trips to sites 6 and 10. Multiple index tests were conducted on this restricted choice data set (N=195) using various values of time. If the revealed preference test results for this restricted choice set are markedly better than the full choice data set, then there is evidence that the proper sub-utility function operating over the site choice of recreational sheep hunters in Alberta contains only the remaining eight sites.

The first test involved choices with no values of time. The results of this test and of a similar test on the full data set (from Table 5) for comparison are shown in Table

11. The outcomes of each of these tests are the same: the choices of hunters represent a significant violation of the axioms of choice according to Tsur's test. These results do not support the eight site choice set over the ten site choice set.

The dependence of this suggestion on the prices used in the test was investigated by incorporating values of time using the income based wage rates. These wage rates were used because the previous tests described in preceding sections identified them as better to use than occupation based wage rates. The results for the full wage rate and one-third wage rates are shown in the last four rows of Table 11. Once again the test results are remarkably consistent between the full and restricted choice sets. Tsur's test suggests that the choices in either group do not significantly violate the SARP in either wage rate category. These findings imply that use of the eight-site choice set is no better than using the ten-site choice set. Therefore, despite the observation that the two sites removed may be readily discernable by the hunters from the other eight, choice behaviour in these data can perhaps be adequately represented by a utility function operating over the full choice set of ten sites.

Table 11. Results of the Multiple Index Revealed Preference Tests Used to Investigate Separability in Site Choice by Bighorn Sheep Hunters (N=195).

Data Set	Value of Time[1]	ρ	Variance[2]	% Choices Violating SARP	Mean Error[3]
10 Sites[4]	0	1.140	0.946	80	0.4289
8 Sites[4]	0	1.110	0.871	81	0.4319
10 Sites	wage/3	0.184	0.724	76	0.1654
8 Sites	wage/3	0.182	0.729	75	0.1680
10 Sites	full wage	0.208	0.844	76	0.1585
8 Sites	full wage	0.199	0.843	75	0.1621

[1] Values of time were calculated using income derived wage rates category (Table 2).

[2] Refers to the variance of the log of expenditures.

[3] Refers to the mean of one minus the individual errors from the perturbation vector.

[4] The test results for these samples represent significant violations of the axioms of revealed preference because ρ>variance.

6.0 CONCLUSIONS

6.1 The Validity of the Traditional Travel Cost Model

The first test of the traditional TCM (Table 5) assumed that the prices generated by the model represented the "true" ones. The results suggested one of two possibilities: 1) that sheep hunters were not rational in the sense of maximizing a utility function; or 2) that the model used was incorrect. This latter possibility was explored by changing the assumption of the prices being correct to a maintained hypothesis of rationality by the hunters, and then exploring various reasons why the model was not reflecting rational behaviour by recreationists. The first of these explorations involved modifying the model to include various interpretations of the opportunity costs of time. The results of these investigations suggest that the behaviour assumed in the traditional travel cost model comes closer to economic maximizing behaviour when these costs are incorporated. This suggestion supports the research by numerous investigators who claim that the value of time must be incorporated in travel cost models in order to derive accurate measures of recreation benefits (e.g. Knetsch 1963; Cesario 1976).

The question remains, however, as to what the values of time are, and how researchers can measure them reasonably accurately using information derived from traditional recreation user surveys. This question was investigated in this study through the use of wage rates derived by some ideas of the actual wages earned by individual recreationists using their reported occupation and income level. These wage rates were used to value travel and on-site recreation time, and were incorporated with travel costs to derive a total price for recreational trips. Operating under the maintained hypothesis of rationality, and investigating the recreation site choices of hunters with this hypothesis, the results suggest that income is better than occupation in determining values of time.

Another investigation of the TCM in this study involved an assessment of heterogeneity in the sample of recreational sheep hunters. Results from Tsur's test suggests that the hypothesis of rationality could be supported in various strata of the data under the condition that positive values of time be included in the determination of travel costs. However, income strata may be consistent with the hypothesis without values of time incorporated explicitly into the travel costs. However, results using the income stratification may be related indirectly to the value of time issue in that income strata represent groups with similar values of time. In any case, this study suggests that income is probably the best socioeconomic variable to use in stratification. A similar result was found by Adamowicz and Graham-Tomasi (1989).

A number of interesting results were obtained from the various stratifications of the data. For example, it was observed that the number and significance of violations of the axioms of revealed preference increased as the wage rate increased in value. Incorporating values of time made these data more consistent with the axioms. These results support the contention that there is considerable variability in the values of time, and that researchers should be particularly concerned with these values in higher wage rate categories in applied studies.

Another result of the stratifications suggests that there may be different fractions of wage rates which should be used in various strata of data. It seems obvious that this may be related to an hypothesis of considerable heterogeneity among recreationists on values of time. However, relatively simple procedures must be developed if travel cost models are to be applied effectively in policy analyses, and these procedures should adequately account for the possibility of heterogeneity in time values. Although the results reported here on specific fractions are speculative, this study suggests a promising line of future research in using revealed preference theory to test empirically the appropriate fractions of wage rates used to value time in various strata of a recreation data set.

Stratification of the sheep hunter data by years of experience hunting big game species supports an interesting speculation on the value of time. A pattern of consistency with SARP was identified within this method of stratification: the choices of hunters in the middle strata were more inconsistent with SARP than the other strata (Table 8). This pattern may be related to some unique aspects of behaviour associated with recreational hunting. For example, a suggestion to explain the severity of violations noted for this middle experience category relates to the work of Jackson et al. (1979).

Jackson et al. (1979) studied the interactions between behavioural attributes of hunting and hunting experience. They noted the following trend of hunter development as experience increases: a "shooter" stage → a "limiting-out" stage → a stage where the focus is on trophies → a methods stage → and finally a "mellowing-out" stage (note their terminology used here). Decker et al. (1987) have confirmed this developmental pattern and relate it to changes in the level of the goals of the hunting experience. Hunters move from an affiliative or achievement orientation to a more appreciative one.

Given these observations on hunter development, one could argue that travelling time may not be as critical a factor in selecting hunting sites for the early stages of development. Similarly, hunters in the late stages have already spent time previously finding appropriate hunting sites and may not be as concerned about harvest success. Thus, time for these strata may not represent a high cost; it might even contribute to utility rather than to price. It is in the middle stages, however, that time may be an important cost. These hunters may focus more on the aspects of the site in searching for experiences which relate more to their quarry. Thus, time spent travelling rather than hunting could be a significant portion of the total cost of the trip. These aspects of behaviour suggest that researchers trying to measure economic benefits should consider motivations and behaviours associated with specific recreational activities. Understanding these may assist researchers in selecting appropriate variables to use in stratifications of recreation data to account for demand heterogeneity.

Finally, an examination of the possibility that the original test of the travel cost model failed because the choices tested involved the entire set of available sites, and not some smaller sub-set, was performed. This investigation involved two theoretical dimensions: that the wrong choice set, and hence the wrong utility function, was assumed in constructing the travel cost model; or that the utility function operating over the choice of sheep hunting sites was separable. Two sites were removed from the data set. These two sites were chosen by considering some obvious differences between various characteristics of the two sites and the remaining sites. The hypothesis of rationality was investigated with this restricted choice set. Both the restricted and the complete set of choices were consistent with the hypothesis when values of time were considered. This result identifies that there was no improvement in consistency of the choices with the axioms when eight sites rather than ten were considered. Thus, in constructing a travel cost model using this data set, the ten site choice set was a valid assumption.

Overall this study supports the consistency of the traditional or HCK travel cost model utilizing individual observations with utility maximization. This consistency, however, is dependent upon the inclusion of appropriate values of time. Some suggestions about what these values are, and how to incorporate them were gained in this study.

6.2 Using Nonparametric Analyses to Study Travel Cost Methodologies

This study reveals that nonparametric demand theory can be applied, and is useful in refining TCM analyses. In the present study it was used to investigate the consistency of the TCM with utility maximizing behaviour, value of time issues, demand heterogeneity, and separability. These issues have been identified as concerns with most applied uses of the model (Fletcher et al. 1990). Although nonparametric demand analysis has been used to examine individual trips in a travel cost model framework (Adamowicz and Graham-Tomasi 1991), this thesis describes the first attempt to use these techniques to test the traditional TCM.

This study also appears to be the first to utilize Tsur's (1989) approximate test for revealed preference conditions. This test seemed to be a more appropriate test than those suggested by Varian (1985, 1987a) because it provides a degree of significance of violations and produced some additional outputs that can be used to explore the results. However, it was disturbing to find a large number of violations of the axioms of choice in data that was judged to be "significantly" consistent with them. For example, in Table 3 (row 2), the test for the SARP utilizing values of time derived using income levels implied that the 226 hunter choices were collectively consistent with SARP despite 172 of the individual choices violating SARP. As mentioned, this finding suggests that the 172 individual choices were "not far" from being maximizing choices. However, inspection of the perturbation vector containing these individual errors (Appendix 2) did not generally support this suggestion. Some errors were large, ranging from 0.86373 to 0.60859. Considering that errors become more "serious" as they approach 1.00000, some concern is warranted as to the validity of this test.

Despite the question of significance, however, the number of violations of the SARP found in this sheep hunter data set are relatively large when compared with the number of violations found in other applied studies testing revealed preference conditions. For example, Adamowicz and Graham-Tomasi (1991) found about 2-5% of trips taken by individual sheep hunters violated the axioms. However, their analysis utilized individual trips as the level of analysis, not the entire choice of trips by a hunter over the hunting season. Other workers, utilizing time series data, have found few violations. Tsur (1989) detected 33 (22%) of 150 months of meat consumption data that violated the axioms; Swofford and Whitney (1986), testing combinations of monetary assets held during 44 time periods, found that on average only 1-3% of the consumption bundles tested violated the axioms; and Chalfant and Alston (1987) investigated a number of time series data sets of meat consumption and generally found none or few violations of the GARP. Of the tests of various data described in this thesis only the strata of Students completely satisfied the axioms (Table 5). The question that begs an answer, therefore, is how comparable are the results of the revealed preference tests reported in this thesis with those using other data sets of recreation choice behaviour?

For a number of reasons the results from these studies may not be directly comparable due to differences in the type and structure of data and the nature of prices. First, at the present time this study is the only one to investigate the consistency of "aggregate" recreation behaviour with utility maximization using revealed preference conditions. The only other study to investigate consistency of recreational data is Adamowicz and Graham-Tomasi's (1991) which utilized the same data as the present study, but used an individual rather than an aggregate level of analysis.

Second, this study utilized cross-section data in deriving aggregate behavioural measures of recreational site choice. Most of the other studies employing nonparametric demand analyses used aggregate time series data. These types of data could be masking the degree of individual variability inherent in choice behaviour over time. Adamowicz and Graham-Tomasi's (1991) study, although utilizing cross-section instead of time series data, represents perhaps the most appealing approach because it compares single choices made by individuals. Their approach may be more theoretically consistent than this and other studies in examining utility maximization.

Finally, the prices (i.e. the values of time) used in the nonparametric tests in this thesis are hypothetical or constructed. The other studies reported above used prices that were derived, either wholly or in part, in markets. Although considerable adjustments were made to the non-market prices incorporated in the travel cost models used in this thesis, they may only be representing the true prices to a particular degree. Further adjustments to these prices based upon more complete socioeconomic data and/or a better idea of the behaviour associated with recreational sheep hunting, may provide fewer violations of the axioms of choice. It should be noted, however, that non-market valuation methods may not be perfect in trying to represent the hypothetical market values of public goods. A tentative conclusion to be drawn from this present study is that the traditional travel cost model may, under certain conditions, represent these prices appropriately enough to be consistent with economic theory. This lends considerable support to the use of the traditional travel cost model in measuring non-market recreation benefits.

6.3 Suggestions for Further Application of Nonparametric Demand Theory in Travel Cost Models

1. A major question worth investigating is the generality of the results obtained in this thesis. One direction that could be pursued is to attempt to replicate the results using other recreation data sets. Sheep hunting is a specialized form of recreation with well-defined choice sets of sites, a need for expensive equipment (e.g. all-terrain vehicles), and a very complex milieu of goals and objectives of a trip relating to satisfaction. Other forms of recreation, such as camping or fishing, differ considerably from sheep hunting. Using nonparametric demand analysis to test the TCM in those data sets may yield different results.

2. The use of nonparametric demand analyses in determining what are the relevant choice sets for recreational activities is an avenue worthy of exploration. In this study, for example, only two possible choice sets were

investigated: one of ten sites and the other of eight sites. These choice sets were selected based upon what was thought to be an obvious grouping of certain characteristics (e.g. remoteness and regulation). A more appropriate direction with this particular data set in the future would be to apply factor analysis in devising groups of sites based upon a variety of site characteristics. This approach could be applied to other recreation data in attempts to accurately specify appropriate choice sets for benefit estimation.

3. There is some question regarding the results from Tsur's test in that despite a large number of individual violations, the choices were found to be consistent with the axioms of choice. This could be studied further by considering more fully the vectors of errors resulting from Tsur's test. For example, it may be instructive to relate the errors to particular choice bundles, or to particular sites. An attempt was made in this study to compare the errors of particular individuals appearing in the strata that violated SARP according to Tsur's test. No definite pattern was found.

4. An additional line of enquiry involves the use of nonparametric analysis in deriving welfare measures from the TCM.

5. Other types of stratifications could be investigated in TCM analysis. One of these could be a stratification by choice set. In this study and virtually all others using travel cost methods, the choice set of recreation sites is imposed on the recreationists. If researchers could define the choice sets of individuals and stratify a set of data by these choice sets, revealed preference tests on these strata would be more theoretically consistent with individual choice behaviour.

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APPENDIX 1

1. The GAUSS Program Used to Calculate the Single Index

```
@SEARCH FOR SINGLE VALUE EFFICIENCY VALUE FROM VARIAN "THREE
PAPERS ON REVEALED PREFERENCE                              @

#INCLUDE SARP.ERR; #INCLUDE PROSARP.ERR; #INCLUDE GARP.ERR;
#INCLUDE PROGARP.ERR;
clearg viol;

PROC SSEARCH(C,P,X);
LOCAL ERR1,ERR2,ERR3;

CLS;
PRINT"================= COMPUTING EFFICIENCY INDEX
=========================";
PRINT"================= EFFICIENCY INDEX FOR SARP
=========================";
SCREEN OFF;
VIOL=1; @TO START ALGORITHM @
ERR1=1.0;
DO UNTIL VIOL.EQ 0; ERR1=ERR1-.05;
PROSARPE(C,P,X,ERR1);
ENDO;

VIOL=1;
ERR2=ERR1+.05;
DO UNTIL VIOL.EQ 0; ERR2=ERR2-.01;
PROSARPE(C,P,X,ERR2);
ENDO;

@ The remaining loop calculates the efficiency index to the third
decimel.
  It is commented out but can be used if required.
@

VIOL=1;
```

```
ERR3=ERR2+.01;
DO UNTIL VIOL.EQ 0;ERR3=ERR3-.001;
PROSARPE(C,P,X,ERR3);
ENDO;

SCREEN ON;
FORMAT 4,2;
@PRINT "    EFFICIENCY INDEX          "               ERR2 ;@
FORMAT 4,3;
PRINT "    EFFICIENCY INDEX           "               ERR3  ;
  RETP("");
ENDP;

PROC GSEARCH(C,P,X);
LOCAL ERR1,ERR2,ERR3;

CLS;
PRINT"================= COMPUTING EFFICIENCY INDEX
========================";
PRINT"================= EFFICIENCY INDEX FOR GARP
========================";
SCREEN OFF;
VIOL=1; @TO START ALGORITHM @
ERR1=1.0;
DO UNTIL VIOL.EQ 0; ERR1=ERR1-.05;
PROGARPE(C,P,X,ERR1);
ENDO;

VIOL=1;
ERR2=ERR1+.05;
DO UNTIL VIOL.EQ 0; ERR2=ERR2-.01;
PROGARPE(C,P,X,ERR2);
ENDO;

@ The remaining loop calculates the efficiency index to the third
decimel.
  It is commented out but can be used if required.
@

VIOL=1;
ERR3=ERR2+.01;
```

```
DO UNTIL VIOL.EQ 0;ERR3=ERR3-.001;
PROGARPE(C,P,X,ERR3);
ENDO;

SCREEN ON;
FORMAT 4,2;
@PRINT "    EFFICIENCY INDEX              "            ERR2 ;@
FORMAT 4,3;
PRINT "    EFFICIENCY INDEX              "            ERR3 ;
  RETP("");
ENDP;
```

2. The GAUSS Program Used to Calculate the Transitive Closure of a Matrix (from Varian 1982)

```
@CLEAR R,M,M1,V,VIOL,TOTAL;@
@ ************************************************************** @
@COMPUTING TRASITIVE CLOSURE TO EVALUATE SARP 2 (VARIAN, 1982),
 USES R MATRIX ABOVE AND COMPUTES
 "IF P(i)X(i) GT OR EQ P(i)X(j) AND P(j)X(j) GT OR EQ P(j)X(k), THEN
  X(j) IS REVEALED PREFERRED TO X(k)"
  RETURNS A MATRIX "TCOUT" WHICH CONTAINS A 1 IF X(i) REVEALED PREFERRED
  TO X(j) AND A ZERO OTHERWISE.                              @
@******************************************************************* @

PROC TCLSR(M);
    LOCAL I,J,K,RC,TCOUT;

    RC=ROWS(M);
     K=0;
     do until K==RC ; K=K+1;

      I=0;
      do until I==RC;I=I+1;

           J=0;
           do until J==rc;J=J+1;
           IF M[I,K]==0 OR M[K,J]==0;

           ELSE;  M[I,J]=1;
           ENDIF;

          endo;

      endo;

     endo;

     TCOUT=M;
call varput(TCOUT,"TCOUT");
     RETP(TCOUT);
ENDP;
```

3. The GAUSS Program Used to Perform Tsur's (1989) Test

```
#include tclsr;
PROC TSUR(C);
@
Input:       a matrix of expenditures of the form C(i,j)= P(i)*X(j)
Output:  the value of "rho" from Tsur 1989 which can be used to
compare to the variance of the log of actual expenditures.  If
the estimate of rho is greater than the variance of the log of
expenditures ("sig") then one cannot except the null hypothesis
that the underlying data satisfy the SARP.
The values "rho" and "sig" are returned to global memory.
Also returne[illegible] memory is the vector "m" which is the perturbation
vector.
@

local m,ce,re0,gge,rho,i,j ,re,q.mc,sig;

m=ones(rows(c),1);
ce=c;

q=1; do until q==rows(c);
```

```
    ce=diagrv(ce,m.*diag(c));
    re0=zeros(rows(c),cols(c));

    gosub sub1;


if sumc(gge).eq 0; goto rhostep; endif;

    j=1; do until j==rows(c)+1;
         if (gge[j,1].eq 1);
         mc=(c[j,.]./c[j,j])';
         mc=re[.,j].*mc;
         mc=miss(mc,0);
         mc=packr(mc);
         m[j,.]=minc(mc);
         endif;
    j=j+1;
    endo;
q=q+1;
endo;

rhostep:
rho=sumc((ln(m)^2)./rows(c));
call varput(rho,"rho");
@compute variance of log of expenditure vector c(i,i)@
sig=(stdc(diag(ln(c))) )^2;
call varput(sig,"sig");
call varput(m,"m");
call varput(re,"re");
call varput(re0,"re0");
retp(rho);
@ ------------- SUBROUTINES ------------- @
SUB1:
    i=1; do until i==rows(c)+1;
    j=1; do until j==rows(c)+1;
    if ce[i,i].ge ce[i,j]; re0[i,j]=1;
    else; re0[i,j]=0;
    endif;
    j=j+1;
    endo;
    i=i+1;
    endo;
re=tclsr(re0); @compute transitive closure from tclsr program@
    gge=zeros(rows(c),cols(c));
    i=1; do until i==rows(c)+1;
    j=1; do until j==rows(c)+1;
    if (re[i,j].eq 1).and (ce[j,j].gt ce[j,i]); gge[j,i]=1;
    endif;
    j=j+1;
    endo;
    i=i+1;
    endo;
    gge=sumc(gge');
    gge=gge .gt 0;
    return;
endp;
```

APPENDIX 2

A summary of the individual errors (N=226) resulting from a revealed preference test of the sheep hunter data incorporating income derived wage rates (see Table 3: row 2). These errors, sorted in descending order, were derived by subtracting each entry in the perturbation vector from one. Thus, values of 0.00000 indicate that the choices made by that individual were consistent with the SARP, while values approaching 1.00000 indicate the highest severity of violation of the SARP.

0.86373
0.85407
0.76175
0.75586
0.73096
0.72781
0.71819
0.71776
0.71148
0.69717
0.69143
0.66776
0.66408
0.65244
0.65181
0.64460
0.64246
0.64060
0.63718
0.63521
0.60859
0.59698
0.59035
0.57035
0.55643
0.54949
0.54512
0.53460
0.52619
0.52528
0.50672
0.50608
0.50373
0.49956
0.48714
0.45693
0.45603
0.43807
0.40232
0.38335
0.38313
0.37683
0.36614
0.36473
0.36120

0.35458
0.34844
0.33892
0.33333
0.33050
0.33039
0.32538
0.32375
0.32240
0.32022
0.23503
0.23118
0.22870
0.21951
0.21354
0.19914
0.19680
0.18408
0.17819
0.16581
0.14665
0.14612
0.13827
0.13110
0.11628
0.11059
0.10198
0.09630
0.08850
0.08494
0.08481
0.08295
0.08105
0.07912
0.07900
0.07826
0.07718
0.07160
0.06941
0.06756
0.06654
0.06610
0.06534
0.06369
0.06128

0.05897
0.05886
0.05791
0.05677
0.05314
0.05207
0.05121
0.05049
0.05041
0.04236
0.04178
0.04148
0.04146
0.04145
0.04086
0.03987
0.03987
0.03970
0.03963
0.03934
0.03901
0.03748
0.03644
0.03632
0.03608
0.03504
0.03487
0.03300
0.03158
0.03127
0.03091
0.03038
0.03027
0.02633
0.02617
0.02572
0.02488
0.02405
0.02378
0.02299
0.02191
0.02166
0.02067
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0.01844

0.01825
0.01763
0.01761
0.01661
0.01579
0.01501
0.01501
0.01489
0.01441
0.01316
0.01305
0.01270
0.01267
0.01261
0.01180
0.01106
0.01083
0.01050
0.01030
0.01006
0.00876
0.00815
0.00793
0.00711
0.00697
0.00688
0.00655
0.00583
0.00577
0.00502
0.00404
0.00318
0.00294
0.00256
0.00202
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